MILITARY VERSUS PRIVATE INDUSTRY VERSUS UNIVERSITY

CONTROL AND ADMINISTRATION OF

MILITARY RESEARCH AND DEVELOPMENT

by

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Cambridge, Massachusetts
May 10, 1957

Professor L. F. Hamilton
Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

Dear Professor Hamilton:

In accordance with the requirements for graduation, I herewith submit a thesis entitled "Military Versus Private Industry Versus University Control of Administration of Military Research and Development."

I wish to take this opportunity to thank my advisors, Professor Herbert Shepard, Chairman; Professor Howard Johnson; and Professor Albert Rubenstein for their constructive criticism and guidance. Special appreciation of the help of the Chief, Bureau of Ordnance, U. S. Navy, and members of the Bureau of Ordnance, is also due. Finally, I would like to acknowledge the suggestions of other members of the Institute Staff, officials of the Department of Defense, Private Industry and Universities.

Sincerely yours,

Signature redacted

Edward E. Harriman

EEH:ps
Encl.

MILITARY VERSUS PRIVATE INDUSTRY VERSUS UNIVERSITY CONTROL AND ADMINISTRATION OF MILITARY RESEARCH AND DEVELOPMENT

by Edward E. Harriman

Submitted to the School of Industrial Management on May 17, 1957, in partial fulfillment of the requirements for the degree of Master of Science.

ABSTRACT

The control and administration of Military Research and Development is becoming increasingly important. There exist today differences of opinion among individuals within and between our military departments, private industries, and universities as to how our military research and development program should be controlled and administered.

Each of the groups involved feels that it has something unique to offer to the overall research and development program and each feels that it can do a better job than the next fellow.

The Department of Defense Research and Development Program has been greatly influenced by current considerations for National Defense. These have been of overriding importance and have constituted the most important influence upon governmental organization for science. Defense research accounted for about 86 cents out of every Federal Research dollar in 1954 as against an estimated 20 cents in 1938. The National Science Foundation in its report on the Organization of the Federal Government for Scientific Activities[1] reported that the heavy emphasis on defense research does not, however, imply a diminishing interest in research of other kinds. The new possibilities opening by scientific discoveries, combined with increased public interest, have led to a great expansion of research in a number of other fields, notably in the peace-time use of atomic

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1. National Science Foundation, NSF. 56-17, Organization of the Federal Government for Scientific Activities, dated 1956, U. S. Government Printing Office, Washington 25, D. C.

energy and in the agriculture and medical sciences.

The National Military and Defense requirements have raised the Federal Budget and the Federal Debt to such a level that it has become urgent to seek the most efficient means of organization in every sphere of activity, including the government's research program. In this respect, this thesis endeavors to study the advantages and the disadvantages of and to clarify the problem of military versus private industry versus universities in managing, controlling and administering the Defense Department research and development program.

Thesis Advisor: Professor Herbert Shepard

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PROLOGUE

"Never let any government imagine that it can choose perfectly safe courses; rather let it expect to have to take very doubtful ones because it is found in ordinary affairs that one never seeks to avoid one trouble without running into another; but prudence consists in knowing how to distinguish the character of troubles, and for choice to take the lesser evil."

Nicolo Machiavelli,
The Prince, p. 127.

CHAPTER I

PROBLEM AND SETTING, PURPOSE OF THE STUDY, RESEARCH METHOD EMPLOYED AND MAJOR CONCLUSIONS

PROBLEM AND ITS SETTING

The control and administration of Military Research and Development is becoming increasingly important. The obligations and expenditures for research and development have increased from less than $1 billion in 1940 to over $2.7 billion for direct research and development, plus $3-4 billion for indirect expenditures, for a total of $6-7 billion research program in 1957. Taken as a per cent of total Government's budget expenditures for all purposes, research and development in 1940 comprised 0.8 per cent. In 1956 the research and development expenditure as a per cent of the total budget was approximately 4 per cent. The Government is sponsoring over 55 per cent of all research and development being conducted in the United States and the Department of Defense administers 85 per cent of all the Government's research and development funds. It has, therefore, become urgent to seek the most efficient organization, administration and management of the military research program.

There exist today differences of opinion among individuals within and between our Military departments, Private Industry, and Universities as to how our Military research and development program should be controlled and administered.

Each of these feels that it has something unique to offer to the over-all research and development program and each feels that it can do a better job than the others.

This thesis reviews research and development in the following types of organizations: Large Private Foundations, Cooperative Organizations, Nonprofit Research Institutes, Commercial Laboratories, Private Industry and the Federal Government (including Department of Defense, Atomic Energy Commission and the National Advisory Committee for Aeronautics).

PURPOSE AND METHOD OF SURVEY

This study of "Military versus Private Industry versus University Control and Administration of the Military Research and Development" is being conducted on the status of research and development in the United States, in an effort to clarify many misunderstandings that exist today among the many and varied reports by recognized experts concerning the control and administration of military research and development. It is the

intent of this thesis to present pertinent data on the major types of organizations conducting research and development. The question to be answered is, "Is the Military, Private Industry, or the University most capable of coordination, control and administration of the over-all Military research and development program?"

The author conducted a survey of the research activities of independent and quasi-independent research institutes in the Government, Private Industry and Universities. Studies of the past history and present status of research done by the various types of organizations were made. These studies provide information on the following aspects of research conducted or supported by these organizations: (a) the current status of research; (b) historical trends in research; (c) the manner in which research is financed and administered; (d) the purposes for which the organizations were established; (e) the extent to which basic research is performed; (f) the relationships and interactions between research organizations in Private Industry, Universities and the Government; (g) the prospects for additional research; (h) scientific manpower; (i) dissemination of scientific information.

In addition to gathering statistical information on dollar expenditures, sources of funds, scientific manpower and the like, this thesis investigates the more qualitative aspects of the organizations described and

has attempted to delineate the reasons for the existence of the different organizational forms which perform apparently similar work, to explore the extent to which the original objectives of these organizations have been met, and to determine whether their basic purposes and organization structure have changed over the years.

RESEARCH METHODS EMPLOYED

A questionnaire was mailed to 100 addressees who were considered to be a representative sample of recognized experts in the field of research and development in Government, Private Industry, and Universities. The forwarding letter stated that this author was a Sloan Fellow and proposed to do a thesis on the subject, "Military versus Civilian Control and Management of Military Research and Development". The letter further stated that it would be greatly appreciated if they would fill in the questionnaire or write a letter to this author if they had an opinion as to the feasibility of this subject as a thesis subject, or if they knew of any references which pertain to this subject.

Eighty-nine persons returned the questionnaire, forwarded reports or sent a letter. Over 95 per cent of all the replies stated that they considered the proposed thesis very timely and stated that it should be very interesting, as it is a subject that a large number of

the nation's foremost scientists and military men have commented on in various forms and places from time to time. The majority of the persons contacted stated that if there was any way in which they could be of further service, that the author should not hesitate to call upon them.

Five per cent of the questionnaires stated that they did not think the subject a good thesis subject or that they questioned the advisability of taking on such an undertaking without a sizeable staff, considerable travel funds, etc. The choice comment among the negative responses was that it was doubtful if there was enough material on this whole subject to warrant an individual doing a thesis, as it is largely an unplowed field and one person doubted that it would be possible to develop a thesis on the subject from an "ivory tower" in Cambridge.

Personal interviews were held with approximately 50 persons from private industry, universities and the federal government. These interviews were conducted in an effort to probe more deeply into the research activities, policies, procedures, funding, management, etc., of the research programs of Private Industry, Universities, and the Federal Government.

Personal interviews were conducted in Chicago, New York, Washington, D. C., and Boston. The objective was to interview the officials who were primarily respon-

sible for the research to obtain further insight into the research organizations, policies and procedures.

The interview sought to obtain information on social science research as well as natural science research and in organizational matters as well as research in the physical sciences including engineering and development. The result of the personal interviews was a much greater insight into and a much greater appreciation of the views, attitudes and policies of the various organization types studied.

MAJOR CONCLUSIONS

In accordance with the above considerations and an evaluation of the information obtained by this author's survey of the literature, survey by questionnaire, and by personal interviews, it is the opinion of this author that:

1. It would NOT be possible to contract out to Private Industry or to Universities the overall control and administration of Military Research and Development.
2. Contractor operated laboratories both by private industry and by Universities are feasible and desirable. This new and steadily growing arrangement has been particularly well

suited to research in broad problem areas associated with weapon systems development. Each military department has also used such centers for the conduct of operations research.

3. The Government, private industry and universities are interdependent upon each other to an extent considerably greater than most people realize. The immediate urgency of Defense preparedness combined with the military duty of defending our country, as well as the duties and responsibilities of Private Industry and Universities must be coordinated toward the end result of the most research and development possible with the least expenditure of manpower and funds in the shortest time schedule possible.

CHAPTER II

RESEARCH AND DEVELOPMENT IN THE UNITED STATES MILITARY PROGRAM

Research and Development in the U. S. Military Program; Explanation of the Federal Government's Research Program; Size of the Federal Government Research and Development Program; Government Support of Scientific Research; Government and Industry Interdependence; Magnitude and Complexity of the Policy Control and Administration of Military Research and Development; Role of Science and Technology in Military Affairs; Over-all Organization and Policy Control of Research and Development Within Department of Defense; Operational Explanation of Department of Defense; Organization and Policy Control of Research and Development in the Military Department.

Research and Development as used in the Military, Universities or Private Industry, can be broken up into various groups. The most common nomenclature is as follows: "Basic" which means to most readers and observers fundamental research or so-called pure research. The next type of research might be considered "applied" research where the fundamental knowledge learned under the basic research program is applied to a specific weapons system, or in the case of private industry to a specific piece of hardware. Unless specifically identi-

fied throughout the remainder of this paper the term research will include basic research, applied research and, in general, anything that is included in the general spectrum of research and development. In general I believe it is correct to state that the term "development phase" consists of the application of existing scientific data and the designing of specific engineering hardware items. It also means that the fundamental principles of engineering and design are applied to new designs and engineering applications on specific pieces of weapon systems, hardware or in the case of private industry for the specific application of known engineering principles and scientific knowledge to a specific hardware product.

The importance of research and development in the U. S. Navy, U. S. Army, and the U. S. Air Force cannot be over emphasized. Prior to World War II significant new developments in weapons systems and military weapons were not viewed with the extreme urgency and priority as they are now. It is commonly recognized throughout all phases of our political, governmental, and military families that significant advances must be made as a result of our research and development programs in order to keep the defense of our country and in order to keep our weapons systems at least equivalent to and in all cases superior to the existing or the now in development weapons of any of our future enemies. In a Riehlman committee hearing in 1954, Assistant Secretary

of Defense for Research and Development, Mr. Donald Quarles, stated:

> "Congressmen, I would tend to put research and development near the top of the list; perhaps just as a matter of prejudice, one might say; but actually I think it is fair to say that I put it (research and development) at the top of the list before I came into the job (Assistant Secretary of Defense for Research and Development). It seems to me we must regard the research and development program as our system in this democracy for mustering the best that science and technology can do for this country and keeping it ahead of our competitors in an international sense, having in mind their great manpower superiority. This seems to me to be the one great bulwark we have to defend this Nation in the future against what would otherwise surely be a superior military force. In the broadest sense, I think the problem here is to bring the military and scientists and the engineers into a common team."[1]

Frequent statements in our newspapers, magazines and by radio and television have informed the American public that, in general, all elements of our government are in agreement with the above statement made by Mr. Quarles.

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1. Hearings before a sub-committee on government operations, Organization and Administration of the Military Research and Development Programs, House of Representatives, 83rd Congress, 2nd Session, June 8-24, 1954, U. S. Printing Office, Hereafter referred to as the Riehlman Hearings, p. 17.

EXPLANATION OF THE FEDERAL GOVERNMENT'S RESEARCH PROGRAM

Throughout the remainder of this report all funding information will apply only to the Department of Defense. It is true that a very important part of the cost of developing atomic weapons for the Department of Defense is funded by the Atomic Energy Commission. And in many cases the majority of the funds for such weapons are Atomic Energy Commission funds. This emphasizes the need for cooperation, control and coordination between the Atomic Energy Commission, the National Advisory Committee for Aeronautics (NACA) and the Department of Defense since these three agencies are involved in the extremely complex direction of the total military research and development program. Each of the above named contract directly with universities, private industries, and in many cases with another Government agency, to conduct a specific phase of a research project for another agency. Within the Department of Defense, the Army, Navy and Air Force each conduct thousands of research projects. In general, these projects are reviewed and coordinated by committees established within the Department of Defense having representation from each of the three services. In addition to this, the activities are reviewed by the Assistant Secretary of Defense for Research and Engineering, and the Bureau of the Budget before being submitted to the President for

inclusion in his budget which is presented to the House for review then to the Senate. Therefore, the specific large project within the Department of Defense must be coordinated much more closely than most outsiders realize before they can be presented to these various reviewing activities. The duties of the Assistant Secretary of Defense for Research and Engineering are given in detail in Appendix 1.

Following World War II, all segments of our military families realized the extreme importance of ultimate weapons systems which result from our Research and Development Programs. Much publicity was given in the press of "push-button warfare". To the general public, and especially to the families of the men who had been away in the service for a long time, this meant that the advancement in science and technology had been such that a small number of men would be able to conduct a war by some means of magic. This seemed to mean that sons, husbands, relatives and friends would not have to serve if we should have a future war. Unfortunately this interpretation of "push-button warfare" is considerably ahead of the current state of technology and science. The one thing that has emerged from this, however, is acceptance by the public, the Congress, the President, the Bureau of the Budget, and various reviewing officials that research and development is an essential part of the military budget. There is a

general feeling throughout the general public that we need and must have the latest weapons systems, intercontinental ballistic missiles, atomic weapons, push-button weapons, and that the necessary funds to proceed on research and development are made available to the Department of Defense in the amount desired, requested or needed to develop such weapons. From the author's personal experience in defending the research and development budgets within the Department of Defense, this is <u>not</u> true. There is not now and there has not been at any time since World War II sufficient funds to conduct all the research projects, weapons systems research, that were desired by the military services. Whenever a new design or idea is approved by all the reviewing officials and the new research project is undertaken, some other portion of the budget must be reduced in order to finance the new project. It is true that in some cases these funds may well come from priority rating, long-range planning, or weapons systems review and coordination.

Much progress has been made in the review, coordination, and control of military projects and weapons systems. At the close of World War II there was very little direct interchange or exchange of information between one research group in the Federal Government and another group. Committees have been set up, within each service, between each service in the Depart-

ment of Defense and between the Department of Defense, universities and private industry (whose express job is) to exchange research and development information which would be of assistance to each other.

The over-all Department of Defense research and development program must be controlled, coordinated and integrated into a balanced program. This requires control and coordination at all levels within each of the departments in the Department of Defense as well as coordination with the Atomic Energy Commission and the National Advisory Committee for Aeronautics. The research and development program must be reviewed by the Assistant Secretary of Defense for Research and Engineering. Ultimate weapons systems and/or superior push-button warfare weapons are still something in the future. Every effort is being exerted by research and development agencies of the Department of Defense and other agencies of the Federal Government to exchange basic research information as well as applied research data and information in order to expedite our advances and achievements in science and engineering.

SIZE OF THE FEDERAL GOVERNMENT RESEARCH AND DEVELOPMENT PROGRAM

The size of the research and development program being conducted in the U. S. Government is extremely

large. The U. S. Commission on the Organization of the Executive Branch of the Government, commonly referred to as the Hoover Commission Reports, stated that:

> The Federal Government through 29 different agencies conducts programs of research and development. On the basis of the budget proposals for appropriations for the fiscal year 1956, the total expenditures of the Government for that year will be about $2,400,000,000, of which about $2,050,000,000 is in the Department of Defense and $350,000,000 by the civilian agencies. A total of at least about 124,000 persons in the military and civilian departments participated in these programs. If we include the research and development carried on by our industries and nonprofit institutions, the aggregate sum probably exceeds $4,500,000,000 annually.
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> This organization of Research and Development in the Government is the largest integrated scientific and technical endeavor that any nation has ever attempted. The programs in the departments reach through the realm of abstract science, the evaluation of scientific discovery into inventions and improvements. In the military departments the development of inventions and improvements in weapons extend into the test of these improvements; the standardization of design; the development of production programs; the placement and coordination of production; and, finally, production must be accompanied by continuous further research and constant evaluation of results.[2]

From the above it can easily be seen that the largest proportion of research and development conducted in this country is supported by the Federal Government.

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2. Commission of Organization of the Executive Branch of the Government, Research and Development in the Government, a report to Congress, May, 1955, p. xi.

The Department of Defense spends over 85 per cent of the government's research and development funds.

The U. S. Commission on Organization of the Executive Branch of the Government, Sub-Committee on Research Activities, reported that of the total research and development funds expended by the Department of Defense approximately 40 per cent is expended in 120 installations operated by the military departments, 49 per cent is consumed by contracts with industry, 10 per cent is expended at universities and other non-profit organizations and the remaining one per cent is transferred to other agencies for research and development services.[3]

Mr. Marion Carey Brewer reports that,

> From a total of just over six million in fiscal year 1941, expenditures increased to seven times that amount in fiscal 1942, more than tripled again the following year, and reached a peak of over $167 million in fiscal year 1945. Although the NDRC and the OSRD expended over $536 million from 1940 to 1946. Although by present standards these expenditures appear rather small in comparison with prewar expenditures for military research and development they were extremely large. In 1938 the War and Navy Departments together

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3. Commission on Organization of the Executive Branch of the Government, Sub-Committee Report on Research Activities in the Department of Defense and Defense Related Agencies, April, 1955, p. 39.

spent less than $15 million on research activities, largely within their own installations.[4]

During World War II most research had been applied research devoted largely to developmental purposes, and by 1945 it was becoming increasingly apparent that basic research of the fundamental type was dangerously lagging in the United States. The scientific professions as a whole were generally convinced that the Government would have to take a definite role in the support of basic research, but the manner in which this should be done was highly debatable. Mr. Don K. Price stated:

"at the end of 1951 the President reduced the budget that was recommended for basic research in military departments by five million dollars and increased the National Science Foundation budget by a similar amount. The Congress was glad to accept the reduction in the military budget, but it struck a figure out of the National Science Foundation budget as well."[5]

This problem is not unique in the above described situation. At all levels of review from the project engineer through the research department heads,

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4. Marion Carey Brewer, "Science and Defense", Doctor's Thesis, Harvard University, Political Science, April, 1956, p. 30.
5. Don K. Price, "Government and Science", New York University Press, 1954, p. 61.

bureaus, agencies and the Secretary of Defense each and every reviewing agency has as one of its objectives to reduce the amount of money appearing on the presented budget. Frequently, these reviewing officials will ask for a recommended allocation for a budget in the presented budget in case they later decide to finance a project which is now just being considered. Whenever these figures are presented usually a cut results on the basis that if you had gone into a new project this old one would have had to have been cut anyway so the cut is made now and the reviewing committee will worry about funding your new project if and when it is approved by all authorities.

The American Council on Education, Sponsored Research Policy of Universities and Colleges, reports that before the expansion of Federal research activities in World War II, research in the United States was sponsored 60 per cent by industry, 35 per cent by the Federal Government, and 5 per cent by Universities. Today research is sponsored 55 per cent by the government, 40 per cent by industry and 5 per cent by the universities.[6]

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6. The American Council on Education, Sponsored Research Policy of Universities and Colleges, Washington; 1954, p. 26.

CHANGE IN GOVERNMENT SUPPORT OF SCIENTIFIC RESEARCH

In private industry, engineers and scientists have become dependent upon the United States Government for the financing and sponsoring of a large majority of their now "in House" operations. The author submits that this is as valuable and of as much help to the government as it is to the individual companies. The difficulty arises, however, when one asks the question, "Now that the government is sponsoring over 55 per cent of the total research being conducted in the United States, would it be possible to contract for the management and administration of this research and development to private industry or to a university?" This writer believes on the basis of the evidence that contractor managed and operated laboratories both by private industry and by universities are feasible. The over-all control, management, administration, and coordination of the research and development program within the Department of Defense would not be possible to contract out to private industry or to universities. The scope of this job is indicated by the large number of review and coordinating committees, agencies, offices and departments that currently exist within each of the Department of Defense and this type of work is the primary responsibility of several of the Assistant Secretaries and their staffs at the time. The inherent diffi-

culties of communication which exist in our current organization would be magnified many times if each research laboratory was contracted for and managed under the sponsorship of a section of industry or under the sponsorship of a particular university. The present customer-user relationship which is developed and maintained by having military men occupy positions within our research and development activities would be lost completely. The ultimate user -- the soldiers, the fighting men, the pilots, or the ship commanders -- would have little opportunity to learn first-hand by communication with their subordinates and fellowmen, who rotate to and from ship to shore research activities, what advances were being made in weapons systems and equipments until these items reached the Fleet, Air Force and Army as hardware items. It is this author's opinion that much of the current feeling of "not invented here" would be magnified by the users under these conditions. It has been reported that an entirely new set of relationships has evolved between the government and science, one in which the Federal Government has become extremely dependent upon American scientists and vice versa. This interdependence is one in which neither the government nor science can withdraw. This new relationship between science and Federal Government has been termed an "Improvised form of Federalism" by Don Price who stated:

> "The contractual system made it possible to have government work done under private salary scales, with none of the civil service red tape, without the restrictions of personnel ceilings, and with greater appearance of long-term security."[7]

Various forms and patterns have evolved for procuring scientists for Federal Government work, within universities, industry and non-profit research organizations. Marion Carey Brewer states:

> "The most common type of contract with industry is that which provides for research and development aimed at improving existing weapons systems and devices."[8]

Usually the particular company involved in each case is already engaged in the production of those items for the government. The research and development is thus similar to work the company might perform if it were producing for competitive sales.

A second type of contract, usually entered into with research institutions and universities, is called the "Master Contract", under the terms of which individual research projects may be performed without having to repeat the negotiation of general terms for each successive project.

A third type of contract is that which is let

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7. Price, Op. cit., p. 77.
8. Brewer, Op. cit., p. 38.

for services in a single extremely broad problem area. This is the type of arrangement under which the various "projects" have functioned. Sometimes special organizations have been formed by universities for this purpose. Project Lincoln, for example, is a research and development program aimed at devising a system for the defense of the North American Continent. The Lincoln Laboratories, in which this project is carried out, are operated by the Massachusetts Institute of Technology entirely separate from its regular university organization.

A fourth type of contract procures the services of special private corporations formed especially for this purpose. Rand Corporation, for example, was established in 1946 under sponsorship of the Air Force for the purpose of studying all Air Force weapons and strategies in an effort to incorporate the most advanced scientific and technical knowledge into the Air Force program. It is a private organization made up of highly qualified individuals drawn from universities and industry.[9]

Associated Universities, Incorporated, also a private corporation, was formed by a group of universities for the express purpose of operating the Brook Haven National Laboratory for the Atomic Energy Commission.

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9. For a description of the Rand Corporation and its program, see: "The War of Wits", Vol. 43, March, 1951, pp. 99-102, 144-158.

The above types of contractual arrangements have been serving to bring scientists into the government and as a result has developed a three-way partnership among private industry, universities and the government. It has been stated that, in addition to the basic advantage, the government is able to obtain the services of scientists who might not be willing to work under the restrictions of government employment. These contract arrangements also permit the government to carry on large-scale operations with universities and industries, largely free of political consideration. Don Price has stated:

> "This new system is one that almost wipes out the distinction between public and private affairs and gives great segments of industry and education a state in the Federal programs."[10]

Many universities are concerned that by taking on additional government contracts they will unknowingly submit themselves to the danger of eventually subverting themselves to various governmental controls. Mr. Lloyd V. Berkner stated that:

> "The University not only has the responsibility for the search for knowledge, but it has an equal responsibility for the transitional process whereby this knowledge can be

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10. Price, Op. cit., p. 78.

made useful to society, through the process of government and industry.

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"It is diversity of support that best guarantees the freedom of thought, and the untrammeled search for the truth. The history of the matter is that the university has always been in danger of domination of a class or a creed, or an organization or by individuals. When it owes its support to a single source it is in grave danger of being intellectually beholden to that source. A university that is wholly endowed may be unconscientiously conditioned to loyalty to the economic system that supports the values of its stocks, bonds, securities and properties. True academic freedom with no predominate allegiance is only possible when the sources of support come from all these, the state, the church, the wealthy individual, and private investments."[11]

Many scientific, educational, and military personnel have observed rightfully that the many and numerous pressures exerted on scientists and engineers to pursue applied military research leading to a specific weapon system or hardware item has left few scientists for the pursuit of basic research, either within industry or in the government. Estimates indicate that universities have only about ten per cent of the 125,000 research scientist and engineer personnel in the United States. Consequently, Dr. James Killian, President of Massachusetts Institute of Technology has pointed out, "the principal load of basic research in the United

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11. Lloyd V. Berkner, "University Research and Government Support", Physics Today, Vol. VII, January, 1954, p. 12.

States is being carried out by about 12,000 scientists and engineers."[12]

GOVERNMENT AND INDUSTRY -- THE GROWING INTERDEPENDENCE BETWEEN THE DEPARTMENT OF DEFENSE AND PRIVATE INDUSTRY

The growing interdependence between the Department of Defense and Private Industry is illustrated by the previous financial figures in this report which were that approximately one-half of the government's research and development funds are spent in contracts with industry. The total research and development funds from the government at the present time are in excess of 2.5 billion dollars annually. While interviewing company officials and representatives, the author of this paper was informed frequently that the administrative and management personnel which the company must make available to handle a large government contract or to manage a laboratory for the government are the same key critical people that the company must use to further its own goal of making the best profit it can for its stockholders, produce the best product it can for the money and to give the best services to its customers for the least amount of money. In one instance the President of a

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12. James Killian, "Military Research in the Universities", The Journal of Engineering Education, Vol. 43, September, 1952, p. 14.

large company doing well over a 100 million dollars worth of research annually in its laboratories informed this writer that over 60 per cent of their total budget was Department of Defense expenditures and that known applications of science and improved products of his company which would further and/or improve their services to customers could not be handled in the laboratory because of the conflict with government work. Therefore as a company policy it would be desirable in the future to reduce the amount of government contracts, to use their key management and administrative personnel in middle management and executive positions to further the goal of their corporate objective. Private industry is becoming more concerned and aware of the extreme importance of research in industry. However, the type of research which industry usually takes on is in the area of applied research.

> "It has been noted that only two American corporations rank high in the support of basic research and, significantly, those two corporations have produced the only two industry-sponsored American Nobel Prize winners."[13]

Mr. Sloan further stated,

> "Industry has been on an increasing research binge ever since World War II, but it still

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13. Alfred P. Sloan, Chairman of the Board at General Motors, <u>Fortune</u>, Vol. 51 (April, 1955), p. 219.

> remains 99 per cent devoted to linkages between applied research and the immediate needs of its sales departments, and its advertising usages have pounded the words <u>science</u> and <u>research</u> out of all shape in the public mind by invoking them in so many trivial and unworthy causes."[14]

It is common knowledge that the relations between individuals and the government can be strained if not difficult at times by the administration of a time-consuming delaying-type of action which result from security investigations on all persons who work on classified projects whether they be at government laboratories, private industries or universities. To this writer it is the administration of these regulations that produce the problems. To the best of my knowledge once an individual has obtained a security clearance it is very easy to have his clearance certified and have the clearance transferred to other selected work, providing the individual has the need to know and security clearance. Admittedly, there are glaring examples of injustice, on the other hand this author knows of numerous examples which were rewarding and tend to overrule the disadvantages of the system.

It is necessary to say that the interdependency of research and development in private industry with the government and vice versa is similar to the

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14. Sloan, <u>loc. cit.</u>

interdependency between the government and universities as far as science, engineering and development are concerned. As long as the Department of Defense sponsors over 85 per cent of all research and development funds spent by the Government, this interdependence for producing the most advanced weapons under the most efficient conditions for the least amount of money will be a joint responsibility of private industry and the government, both military and civilian. The defense position of the United States and possibly the entire world will depend upon the ability of these groups of people to work together under the most harmonious, productive and creative atmosphere.

MAGNITUDE AND COMPLEXITY OF THE POLICY CONTROL AND ADMINISTRATION OF MILITARY RESEARCH AND DEVELOPMENT

The Government (Department of Defense) research and development program is of tremendous magnitude and complexity. Due to various rules and regulations that are in existence, critical materials, and short supply items must be allocated to the Department of Defense on a priority basis before allocation to private industry. Don Price noted that contracting with large segments of private enterprises makes use of managerial talent not available in sufficient quantities within the Government. But, says Price:

> "This very advantage suggests the major weakness of the system: a government that cannot provide adequate administrators for the comparatively minor operating subdivisions of its program is bound to have difficulty in tying those pieces together into a general program that makes sense. ... The basic question is whether the government has an adequate system of top management and enough foresight and experience in preparing its advance plans to unify a vast scientific program into a coherent whole."[15]

ROLE OF SCIENCE AND TECHNOLOGY IN MILITARY AFFAIRS (DIRECTION AND IMPLEMENTATION OF THE MILITARY PROGRAM)

> "... The combination of science, engineering, industry and organization during the last decade created a new framework that rendered conventional military practice obsolete. Radar, jet aircraft, guided missiles, atomic bombs, and proximity fuzes appeared while we were fighting; they determined the outcome of the battles and campaigns, even though their detonating nature was not fully exploited in that contest. Over the horizon now looms radiological and biological warfare, new kinds of ships and planes, and utterly new concepts of what might be the result if great nations again flew at each other's throats."[16]

The interdependence between the civilian scientists and engineers within universities, private industry or the government and with the military personnel of the Military Department have been outlined previously. One of the much talked about areas of study

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15. Price, Op. cit., p. 92.
16. Vannevar Bush, "Modern Arms and Free Men", New York, Simon and Schuster, 1949, p. 3.

in this situation is the inherent difference in thinking mechanism or process between the scientists and the military-trained man.

In the opinion of this writer, the most essential and most important object to be accomplished in the future is that the application of physical sciences to the military program be one which is performed jointly, through a partnership between the civilian scientists, engineers, managers and administrators, and the military engineers, scientists, administrators and managers. There exists today and there has been for many years a basic understanding concerning the respective functioning organization between the civilian policy-making secretaries of the services and the military operating officials of the services. This relationship has worked to the best of this author's knowledge for numerous years very smoothly. There exists today an understandable mutually acceptable working team arrangement between the military and the civilian policy maker, military and civilian scientist and/or engineer. As is true in private industry, wholly within one organization, one division or segment of that company will rally together and work as a team harmoniously with good morale and another section or portion of the organization less team work and low morale will result. What then are the qualities or the differences or what is the situation that produces harmonious

teamwork and high morale in one situation and low morale in another? It seems to this writer that there would be significantly no difference between situations entirely in private industry or a military-civilian team working together for a general purpose.

It is true that in the past mistakes of personnel "make-up" of both the military man and the civilian scientists have been made. Possibly what is needed is a close review of the personal traits and characteristics of both the civilian and the military person before they are put together to work as a team. Each of these individuals will have significant contributions to make to the other. The military man will be an expert on operational requirements and can best determine how a given weapon system should be employed against military forces of the enemy. He will be well informed and will be an expert in military strategy and tactics. The civilian scientists will have knowledge of scientific requirements and a questioning attitude on the application of technical and theoretical functions. The scientists will have an appreciation for basic research, applied research, design and engineering. Therefore, each (military and civilian) has a good deal to offer to each other.

In the American system of government, the President and the Congress have the over-all responsibility. But the military must always operate within

the limits defined by those who have responsibility for political decision making. The civilian policy maker determines "what is desirable" in view of all other considerations; the military advisor and planner determines "what is possible" in a military sense. In practice, of course, there is considerable interdependence. Effort should be made to clearly establish the line of promotion, authority, and responsibility between the military and the civilian authorities. The distinction of two groups with class consciences, rivalries and jealousies cannot exist. The civilians and military must establish mutual respect for each other based upon understanding of the duty and responsibility which each has in accordance with the existing organization lines of authority.

An interesting and authoritative comment on the responsibilities within the Department of Defense was made by Mr. Donald A. Quarles, now the Secretary of the Air Force and formerly the Assistant Secretary of Defense for Research and Development. Mr. Quarles stated:

> "The concept of operation that I have described is based on the premise that the Military Departments are responsible for the research and development operation; that it is fundamental and inseparable phase of the overall responsibility to provide themselves with proper weapons. Among those things considered to be primarily Service responsibilities are

inter-service action to provide for meaningful pre-project coordination, to effect the easy transfer of technical information among Service laboratories, and their contractors and to enter into joint research and development operations to reduce duplication, to promote efficiency, to recommend budgets, and to achieve economy. The Department of Defense role is to promote the doing of these things and to take care of the occasional failure... National security implied the integration of all national factors that can help. The industrial laboratories which you represent are a mainstay of our security structure."[17]

Mr. Albert Talcott Camp (Sloan Fellow 1955-56) stated in his thesis, "Problems in the Integration of Weapons Research Development", that:

"Opinions of Administrators as to the future of integration range from a feeling that progress is satisfactory to one that the situation is rather hopeless. It appears that progress will be slow, but that organizational improvements, the relative stability of defense expenditures, and the growing confidence of all three Services in their ability to develop outstanding weapons are resulting in freer exchange and use by the working groups of their products of research and development. As a means of fostering progress, the wider use of competent civilian and military resident liaison representatives in government-owned laboratories is suggested."[18]

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17. Donald A. Quarles, from the Fifth Annual Conference on Industrial Research; Coordination, Control and Financing of Industrial Research; Albert H. Rubenstein, Editor, King's Crown Press, 1955, 429 pp., "What Military Research and Development Mean to Industry", June, 1954, p. 259.
18. Albert T. Camp, "Problems in the Integration of Weapons Research and Development", Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at the Massachusetts Institute of Technology, May, 1956, p. iv.

OVER-ALL ORGANIZATION AND POLICY CONTROL OF RESEARCH AND DEVELOPMENT WITHIN THE DEPARTMENT OF DEFENSE

It should be noted that there are many coordinating agencies, policy committees, liaison committees, which have been created for the purpose of control, administration, and liaison of research and development projects within the Department of Defense and with other agencies working closely with the Department of Defense. However, there is not planned nor does there exist an organization for the review, control, and coordination of the research and development work performed by the Department of Defense with that of other Governmental agencies. Within each of the Departments of the Department of Defense exist liaison committees for coordination, etc., committees using the extensive staffs of the Department of Defense and all of the military commands. There exists a feeling among some companies, whose Research Directors were interviewed, that industrial laboratories, industrial concerns, and universities would provide better communications between groups and should provide guidance as to what research and development should be conducted by Department of Defense funds.

This writer would like to call attention to the enormous number of civilian employees now employed within the government; the criticism of communications between laboratories would be worse than at present because the current organization structure provides for

some inventor-user communications by the rotation of military personnel.

EXPLANATION OF MILITARY-CIVILIAN RELATIONSHIP

In the Department of Defense, the civilian policy-maker determines "What is desirable" in view of all other considerations; the military advisor and planner determines "What is possible" in a military sense. Mr. Louis Smith stated,

> "This critical interdependence of policy and strategy makes it essential that the military should weigh the strategic implications of policy and that the civilian authority should know the political implications of strategy."[19]

The military responsibility and therefore the ultimate responsibility for strategy and weapons policy resides with the military within the limitations of the above-described relationship between the military and civilian policy-maker. For all practical purposes, therefore, the civilian scientist is an advisor to the military and assists the military planner when requested; he is an advisor as to the scientific capabilities, implications, and performance of any scientific weapons. The

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19. Louis Smith, "American Democracy and Military Power", University of Chicago Press, Chicago, 1951, p. 319.

scientist therefore recommends and advises with respect to "What is possible" and the military determines "What is desirable" in a military sense. One serious problem concerning the role of civilian scientists in the military program is well stated by the following quote:

> "One serious problem concerning the role of the civilian scientist in the military program results from the fact that the scientist performing a purely technical mission within the military organization is sometimes considered an instrument of civilian control and direction when in fact he is not, or at least should not be. His is a function performed by a civilian simply because it is one which cannot be performed at all, or as well, by the military profession. His function is entirely different from that of a politically appointed policymaker in charge of research and development, despite the fact that they may have roughly similar backgrounds and belong to the same professional organizations."[20]

It must be pointed out that entirely too much emphasis is placed by the uninformed upon the "civilian-military" problems. This author has worked for the Department of Defense in research and development since 1946 and prior to that time was in the military service conducting research and development as a military person. At no time in my thirteen years of experience have I ever encountered a situation at a research organization where the two sides of a given problem, situation, or

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20. Brewer, Op. cit., p. 62.

discussion was clearly drawn between the military and the civilians. It is usually a discussion of a scientist with a new idea versus the planner or programmer who has a definite time schedule to which the weapon, the idea, the science or the application is to be applied. The difference of opinions on funding, scheduling, planning, programing, and coordinating would be no different if the individuals involved were all civilian or all military. It is simply the difference of responsibility or area of functioning in which each individual happens to be involved.

PROFESSIONAL RELATIONSHIP

Dr. Ralph Bennett, Technical Director of the Naval Ordnance Laboratory, White Oak, Maryland, presented an excellent description of the relationship between military and civilians:

> "We have here members of two professions, both of them proud professions. The profession of the naval officer is a proud one. He looks back in our Navy to John Paul Jones, to Decatur, Bainbridge, Hull, Farragut, Dewey, and Sims, and in World War II and in our own time, Halsey and Nimitz -- a proud profession with a great tradition.
>
> "However, the scientific profession is also a proud one with a great tradition. We look back to Galileo and Newton, Farraday, James Clark Maxwell, Lord Calvin, and in engineering people like Marconi, Ford, Edison; and in our

> own day in science we have men like the Comptons, Lawrence, Einstein. This, too, is a proud profession, with a proud tradition.
>
> "Neither one of these sets of professions, or these groups of professional people, is well suited to serve as the "hired hand" of the other..."[21]

It must be recognized that both groups are essential to the ultimate and most efficient success of our technological advances in military warfare and it is of the utmost importance that the proper relationship of each be understood by both. The President's Scientific Research Board discussed sources of conflict between scientists and other, non-military professional groups involved in the administration and control of research in the Federal Government. It states:

> "The source of these strains and stresses probably lies in the intensive specialization of training and experience requisite for achievement in each field. The intense specialization necessary to the performance of a rigorously defined task often produces a viewpoint and background that is a barrier to the understanding the importance of considerations outside the realm of specialists.
>
> <u>Scientists</u>
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> "Emphasis on mathematics, rigorous methods of inquiry, attention to physical phenomena, freedom to follow where reason leads, and devotion to detail are characteristic of research. These requirements sometimes give rise to problems when the scientist must work in an environ-

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21. Riehlman Hearings, <u>Op. cit.</u>, p. 502.

ment where his attitude and objectives must be weighted against other objectives that are also important.

Military

"The task of the armed forces is essentially to organize men and materials for a very specific and vital objective -- defense of the Nation. This necessitates clearly defined organization, lines of command, and limits of responsibility. Rotation and interchangeability of personnel, the very antithesis of individualization, are important to the development of capable officers. Conformance to set procedures and a sharp definition of each individual's role is essential. These requirements tend to make for a set of attitudes and assumptions that create problems when military men and scientists work together."[22]

The above quotation identifies an area that is worthy of a much closer look. If the objectives of the civilian scientist and the objectives of the military are such that they are both leading toward a common goal of the most weapons systems equipment available for the least amount of money and therefore the most defense for our country within the Defense Department budget, the individual personality variances of the civilian and the military become much less important. It is true that mistakes have been made in selecting top civilian scientists and mistakes have been made in selecting top military men to work with the research and development program; however, significant changes in or-

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22. President's Scientific Research Board, "Science and Public Policy", Vol. 3, U. S. Government Printing Office, Washington; 1947, p. 33.

ganization structure and goals of the Department of Defense were made during World War II and rapid advances and changes have taken place since World War II. Therefore, this writer submits that a great deal has been learned by both the experimentation, application, and functioning of various types of organizations under various types of civilian scientists and military operators. Many of the mistakes learned by these individuals furnish excellent background information and is being and will continue to be taken into account when selecting both civilians and military personnel for research and development work where it is required that they work together as a team. A new type of military man is emerging in 1956-1957. Several services are indoctrinating professional military scientists into their organizations. The duties of these persons or the duties of selected line officers who have had significant scientific and technological training is to interpret primarily new applications of sciences and new discoveries, creative imagination, investigate scientific principles, and to make explorations the same as is performed by civilian scientists. These particular administrators are not under the same direct military pressure as are the line officers in operations.

In the opinion of this writer, the scientific and military professions now accept the basic fact that cooperation, coordination, and workable partnership in

research and development is essential, both within military research organizations, at universities, and in private industry. The cooperation between military men and civilian organizations requires careful selection of both the military personnel and the civilian personnel who are to be dealing directly with the military. This workable partnership exists today and with proper support from the various review levels on the research and development budget procedures, the now-existing research and development science-military partnership will function efficiently, promptly, and creatively. Many examples can be quoted today where the military and science professions have collaborated to the fullest and produced maximum use of scientific resources. In the years to come, this type of collaboration becomes increasingly more important as a larger percentage of the research dollar is spent on the development of new futuristic weapons instead of minor improvements to old conventional weapons. Many examples exist where the military research and development program has produced items which have been declassified and are now being produced for a better standard of living for our entire communities. This author finds very little in the previously published papers or descriptive studies which have been conducted to indicate that there are basically significant differences between the collaboration and partnership of various levels of management within the

single civilian organization. Most of the material presented in this area is presented on the basis of the difference of attitude between a research and development scientist and a manager or administrator in the policy level who must take the attitude of insisting upon some form of budget, time schedule, and due date for specific items within his coordinated program in order that the best, most efficient, most economical use of his research and development facilities can be made.

The writer believes, therefore, that there are no striking contrasts between the inherent characteristics of a selected military man working in the scientific field and the selected scientific civilian working in the scientific field. The budget limitations apply within the military organization as they apply in any private industrial company and the policy decision must be made as to the priority of a small improvement on an existing conventional weapon as opposed to a gamble or look into the dark for a significant improvement on an unknown time schedule at an unknown cost for an unknown weapon. It is not unusual in the development of a product for an end item to be produced or submitted for production which is not accepted even though the item meets the specifications or the requirements as originally written. Fortunately, this is due to the discovery within a different part of an organization or from some

other source of a better, more economical and more expeditious way of producing an item to do the same job better, more efficiently, and more economically. In this case, the scientist who developed the original weapon has not had the over-all picture and is not in a position to make the policy decision as to whether, from the operational point of view or from the economic point of view his discovery is urgently needed. Only someone with a broad over-all look in a coordinating position with facts available to him on the defense needs at that time is in a position to make a policy decision between this weapon and a conventional weapon which currently exists, or to make a decision to wait for a new weapon which is being developed.

The responsibility for such decisions can easily be divided between qualified military and scientific personnel. Past experience in private industry, universities, and the military indicates that it is extremely unlikely that the persons making these policy decisions would be the same persons who conducted the original research and came up with a weapons design.

The military profession must bring to the scientific laboratories the operational experience, weapons system specifications, and service needs upon which requirements are based. He must have a keen sense of responsibility for the application of any new research and development and in the end it is the military that

is responsible for the defense of our country. The civilian research and development scientist or technician, the civilian policy-maker must provide technical competence and political information on which to make sound decisions. It must be concluded that the military-civilian scientific team can be as much alike as their specific training allows them to be and on the other hand the civilian-scientist and the civilian policy-maker can be just as much different to each other as their training and areas of responsibility require them to be.

In summary, we have three distinct areas of responsibility: first, of applying the operational experience of military personnel to weapons development -- in the writer's opinion this can only be done by the use of military personnel who have first-hand experience in our armed forces; second, the scientific and technical competence of professional men of reputation both military and civilian -- in the writer's opinion the training, past experience, education, and application can be performed equally well by qualified military personnel or by qualified civilians; third, the group of personnel required in the management and administration of a laboratory are policy-making individuals. The civilian and/or military policy-making individual is substantially different from either of the above two types mentioned. He must be of a nature to pay attention to commitments, time

schedules, funding, personnel problems, industrial relations problems and he must be sensitive to the morale of his organization. This job can be performed by either a military or a civilian providing he has had proper training and experience. It is extremely important that in each of the three above-described situations that the best trained and qualified individual be selected on his own personal merits to function in the job more efficiently than any other available individual.

The ultimate success of the military research and development program will probably be measured by the degree of superiority by which we exceed any and all known or potential enemies. The newspapers, press, and radio have recently been quite critical of certain Department of Defense officials and administrators, both military and civilian, for making specific statements about our degree of preparedness or unpreparedness and not supporting it by actual data. The latter situation puts the government employee or the military personnel or the politician in a bad light with many of the readers. If such information were to be made available to the general public via radio, television, magazines, and newspapers, the state of art and the scientific achievements, discoveries, and developments which have been made by our research and development teams would almost immediately be made available to our current or potential enemies. They would have an immediate yardstick on which

to measure our degree of advancement, our accomplishments, and in many cases even the areas in which we are conducting research and development in an effort to obtain both new basic data and new applications of existing sciences and technologies.

Dr. L. V. Berkner states:

> The last war demonstrated that weapons superiority acquired by efficient research and development can be decisive. Therefore, the importance of military research and development to our national safety in the face of determined and ruthless enemies justifies the most careful planning toward its effective organization. The problem of administration of military research and development is relatively new because large-scale military research and development is new. Therefore, if present arrangements for management are imperfect or not suitable to maintain our progress well in the vanguard of the enemy, the failure does not reflect discredit or blame on our military organizations. Rather it reflects the development of our understanding of what form of management of research and development will work and what forms do not work, in light of accumulated experience with different kinds of organizations.[23]

Several committees have studied the above problem. The first of these was the Rockefeller Committee in April, 1953; the second was the Hoover Commission which submitted its report in May, 1955. The Military Operations Sub-committee is frequently and commonly referred to as the Riehlman Sub-committee.

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23. Riehlman Hearings, *Op. cit.*, p. 629.

The U. S. Commission on Organization of the Executive Branch of the Government states that:

> On September 1, 1952, there were 691 military and 1,937 civilians, a total personnel of 2,556 involved in the operation of the Research and Development Board. Approximately 300 devoted their full time to it, and the others were part-time civilian consultants and officers working on committees, panels, and subpanels. On December 15, 1954, the Office of the Assistant Secretary of Defense (Research and Development) in the programming and coordinating structures described above had 81 military and 427 civilians, a total of 508 in the program. Approximately 165 devoted their full time to the program, and the remainder gave part time to it in the same manner as the part time personnel of the Research and Development Board.[24]

The Assistant Secretary of Defense (Research and Development) also exercises a much more effective control and coordination in the budget procedures than was realized by the research and development board, which operated generally without authority. The Assistant Secretary of Defense (Research and Development) was in a position to recommend to the Secretary of Defense approval of departmental programs for the obligation of the available funds, subject to review by the Bureau of the Budget and the controller, and the Comptroller of the Office of the Secretary of Defense. Mr. Don Quarles

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24. Commission on Organization of the Executive Branch of the Government, Sub-committee report on Research Activities in the Department of Defense and Defense Related Agencies, April, 1955, p. 14.

in the Riehlman Hearings stated that, "The Research and Development Policy Council advises the Assistant Secretary for Research and Development on funds, personnel, organization, and the coordination of research and development activities."[25]

The Hoover Commission Sub-Committee on research activities stated that, "The Research and Development Policy Council is 'potentially a most important and effective organizational unit' and suggests the possibility of its eventually becoming 'the most potent and effective instrument for control of the research and development program.'"[26]

ORGANIZATION AND POLICY CONTROL OF RESEARCH AND DEVELOPMENT IN THE MILITARY DEPARTMENTS

Within the military departments each of the services, the Army, the Navy, and the Air Force, have their own policy direction.

Management and Functioning of Research and Development in the Department of the Navy

The Assistant Secretary of Navy (Air) has the responsibility for the broad management and functioning of the research and development process in the Department

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25. Riehlman Hearings, Op. cit., p. 13.
26. Hoover Commission Sub-Committee, p. 12.

of the Navy:

> The fleet operational component of the Naval Establishment, i.e., the Chief of Naval Operations, is responsible for the establishment of the operational (functional) requirements of the fleet as the basis for preparing the technical research and development program, and for evaluation of the end products resulting therefrom, to determine compliance with established requirements. The materials bureau and the Office of Naval Research have direct line responsibility to the Assistant Secretary of Navy (Air) for the planning and conduct of research and development work necessary to fulfill the established requirements, while the Chief of Naval Research, in a staff capacity to (the Assistant Secretary for Air) coordinates the over-all technical research and development effort. Our organization which divides the Navy's work on a functional basis, is actually very similar to that used by several large industrial corporations. Each material bureau, which might well be compared to a manufacturing subdivision of a corporation, is responsible for all phases of the material under its cognizance, including research and development, design and engineering, procurement, installation, and maintenance. In its organization for research and development, the Navy also follows industrial practice in that it has one subdivision, the Office of Naval Research, which is responsible for providing supporting research to meet the common needs of the Chief of Naval Operations and all the bureaus, including fundamental research in areas of peculiar interest to the Navy which is so necessary for the continued progress in engineering and warfare fields.[27]

The "Gates Committee" submitted a report on April 16, 1954, which recommended an organization in which the Assistant Secretary (Air) would be relieved of respon-

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27. Riehlman Hearings, Op. cit., p. 58.

sibility for personnel policy, which he formerly discharged and the authority of the Chief of Naval Research be expanded to include development as well as research.[28] The Chief of Naval Research now has included in his duties the responsibility for the coordination of the entire program of naval research and development. In the opinion of this writer, the Office of Naval Research is primarily a reviewing agency as far as the research and development programs of the technical bureaus are concerned. In addition, the Office of Naval Research controls the management of three field stations. The Office of Naval Research conducts basic research and support of the research programs of the entire Navy. Consequently, within the Navy there is a reviewing and coordinating agency (ONR) to see that there is no unnecessary or undesirable duplication, overlap, or competition. Within the Air Force, the Air Research and Development Command reviews and coordinates all research and development conducted within the Air Force to insure that there is no unnecessary or undesirable duplication, overlap, or competition.

Within the Army the position of Chief of Research and Development exists within the office of the Deputy Chief of Staff for plans and research. This

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28. Gates Committee implementation (SECNAV, 5430.20, June 24, 1954.)

office has the primary responsibility for the planning, coordination, supervision, and direction of the research and development of the seven technical services within the Army. Research and development operations will continue to function within the technical services, but it is contemplated that greater policy control and coordination will be achieved at the departmental levels by the Office of Chief of Research and Development.

Organization Changes

The recommendations of the Riehlman Sub-Committee have been implemented within the U. S. Navy by the establishment of the Assistant Secretary of Air in a capacity of practically full time work on research and development. The above statement is made as an opinion of the writer and not from any official references.

In the U. S. Air Force the recommendations of the Riehlman Sub-Committee have been adapted and implemented by establishing an Assistant Secretary for Research and Development whose full time duty is devoted to the research and development program.

In the Army the recommendations of the Riehlman Sub-Committee have not been adopted and implemented. The Army has designated the Assistant Secretary for Logistics and Research and Development as the office to be primarily responsible for the review and coordination

of their research and development; therefore, his duties are divided between research and development and logistics.

The Hoover Commission Sub-Committee on Research and Development activities recommended the appointment of a single Assistant Secretary for Research and Development with "no other responsibilities" in each military department.[29] Mr. Marion Carey Brewer stated:

> "The present military research and development program is based on the assumption that the program must be operated by the military and through the military organization. There is, however, recognition of the basic fact that the objectives of research and development can be achieved only through the creative work of the nation's civilian scientists. The broad pattern of achieving the required integration of the military and science professions has been: civilian policy guidance, military organization and administration, civilian research, and military development and testing.
>
> Although the top official in military research and development is a civilian, the direction of the operating program is largely a military matter."[30]

Much has been written about private industry and little has been written about availability of management oriented, military-civilian (officer and civilian), industrial-minded and trained personnel. Research and development in private industry is expanding rapidly both

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29. Hoover Commission Sub-Committee, p. 51.
30. Brewer, Op. cit., p. 122.

on government funds and on projects financed by the companies. In my survey of some one hundred industrial companies, universities, and government laboratories with interviews at fifty organizations, it was pointed out to me that many of our largest companies are now hiring policy officials and research and development administrators from government laboratories.

A general statement made by high officials in several companies interviewed was that the amount of work that they currently have in their organizations is more than their current staff and organizations can handle. Scavenging between industrial laboratories and from government laboratories (both civilian and military personnel) has been going on for years. At the present time however, the salary structure of the industrial and university research laboratories is considerably in excess of that at government installations, and it is profitable for these concerns to scavenge from trained and oriented administrators, managers, and scientists. It has been further stated by numerous companies on numerous occasions that as a policy matter it is the desire of the industrial laboratories to concentrate their best skills and best scientists and engineers on the products for which the company is in existence. In other words, since there is a shortage of management, administrative, and scientific personnel, these companies feel that they owe to their stockholders

the assurance that their most efficient and most productive employees will be working for the corporation on its primary goal of making a profit for the stockholder while at the same time producing the most advanced or most efficient equipment at the least cost to the customer.

If one considers from the government side of the question the desirability of maintaining a degree of continuity among the engineers, scientists, managers, and administrators who are familiar with the technical and management problems associated with government work, it becomes evident that immediate action must be taken to maintain these qualified individuals at military owned and operated laboratories or at government owned contractor-operated laboratories. Otherwise, following the normal promotion cycle, company officials and scientists will rotate in and out of the urgent defense projects at a rather rapid rate. After a person has been trained and oriented on the government contract end he would be reassigned to some other duty within the company. This author sees no distinction between this type of rotation and that which is done by the military officer as he rotates from his operational duty to his shore duty providing the military man is not put in a strictly scientific job. If he is put in a policy-making job and he has a general knowledge of personnel administration, programming, planning, coordination, and so forth, he

would be able to adapt himself to the new situations as well as temporary individuals from any other management personnel coordinating organization.

Within the Department of Defense, methods have been established whereby selected military personnel and selected civilian personnel may be educated at any of our recognized universities or educational institutions to develop the person for any job which his organization has in mind for him. Statistics indicate that the military program has been extensively used and is well organized for the advanced training of military personnel, and that considerable use has been made of train-mechanisms for the advancement of civilian employees of the three services. However, in the long range goal of the military departments it appears desirable to make more use of existing regulations.

Extensive use of educational institutions, scientific conferences, industrial management seminars and conferences, should be made for the mutual training, education, orientation, and familiarization of both civilians and military within the government's research and development program and with the civilian contractor-operated government-owned laboratories with outside agencies, private industry, universities, etc.

Direction and Control

Throughout this paper numerous liaison coor-

dinating planning levels of organization within the Department of Defense research program have been described. It is estimated at the present time that within the Defense Department Assistant Secretary's offices there are at least 3,000 employees. The total employees within the Army, Navy, and Air Force for conduct of our research and development program for the fiscal year 1956 were 124,000. The normal communication process between military members of one organization and their friends and acquaintances in the fleet, the normal communication between civilians employed by the Department of Defense by the three services, and between civilian employees and military employees of each of these laboratories is satisfactory.

CHAPTER III

EVOLUTION AND CHARACTERISTICS OF THE FEDERAL ORGANIZATION FOR SCIENCE

Evolution and Characteristics of the Federal Organization for Science; Up to 1947; Since 1947; Department of Defense; Secretary of Defense; Research and Development Board; Department of the Army; Department of the Navy; Department of the Air Force; Contractor-operated Research Centers; Present Organization for the Conduct of Research and Development in Army, Navy, and Air Force.

UP TO 1947

The Federal Government Organization for Science began very soon after the founding of the Republic.[1] It evolved slowly for the first hundred years, but the pace quickened in the first part of the 20th century. Beginning in World War II and continuing into the Post-War period, there was a spectacular growth in the number and size of scientific agencies and in the scope and significance of their work.[2]

Prior to the Civil War the scientific activities

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1. National Science Foundation, NSF. 56-17, Organization of the Federal Government for Scientific Activities, U. S. Government Printing Office, Washington: 1956, 349 pp.
2. Riehlman Hearings, Op. cit., pp. 629-635.

of the Federal Government consisted primarily of observation and collection of data about natural phenomena. The Army's Topographical Engineers were busily engaged in culminating information to aid the Nation's commerce and Defense; the Naval Observatory and the Coastal Survey assisted in this project. The Smithsonian Institute established in 1846, supported several important scientific activities which were taken over and conducted on a large scale by other Federal Agencies. The National Academy of Science was established as a quasi-governmental organization during the Civil War. However, while some important new devices came into use during this conflict, relatively few civilian scientists undertook work on military equipment and weapons.

The National Advisory Committee of Aeronautics (NACA) was established prior to World War I. This marked the beginnings of a research program that was to pave the way for the development of new commercial and military aircraft in the years to come.

The National Research Council was established by the National Academy of Science during World War I as a quasi-governmental organization. This organization was established to make scientific and technical resources more fully available to the government.

The National Defense Research Committee was approved by the President in June of 1940. Its primary

duty was to conduct research and development to supplement that already being conducted by the military departments. This authority was considerably broadened in June, 1940, to include the conduct of research for the creation and improvement of instrumentalities, methods and materials of warfare. The NDRC surveyed 725 colleges and universities and within two months from its establishment, approval had been granted for contracts with 19 institutions. Over 50 institutions had been asked to furnish detailed information regarding the feasibility of conducting at their institutions advanced research in various critical fields. In general, the NRDC worked primarily through educational institutions and in general, all available laboratory facilities were divided among those participating educational institutions. However, certain projects required centralization and in such cases both the scientific and technical staff and the equipment were moved together to a centralized location. It was soon learned, as a result of NDRC experience, that the civilian scientists' specialized knowledge had to be expended beyond the research program. In many cases it became necessary for the designer and the developer to follow a piece of hardware through the production engineering phase and in many cases even into the organization which was going to conduct the production. In addition to this training program, it was necessary to orient the military officers to science.

The common expression among research and development civilians and military of the war period as well as of the peace time era is, "What is needed to defend our country now?"

In the period between 1939 and 1946 the Naval Research Laboratory and other organizations developed radar showing considerable imagination on the part of the laboratories concerned; however, very little acceptance of this research and development resulted or was communicable to the military services. If the large naval aircraft flying the search pattern from Pearl Harbor on 7 December had been equipped with airborne radar of the type which could have been produced on the Naval Research Laboratory designs prior to that time, there is no doubt that the presence of the Japanese fleet would have been disclosed to our commanders at Pearl Harbor. The first airborne radar sets for American aircraft had to be procured from Great Britain after the outbreak of hostilities and about four months before Pearl Harbor.

During the era before 1939 the introduction of adequate communication equipment into the armed forces had lagged behind the general state of the communications art. Only after the beginning of the war were our aircraft fitted on a "crash" basis. The blame for this cannot be placed entirely upon the armed forces. As was true before the war and has been the case since the war,

the funds available to install and equip these latest equipments into our operating vehicles and weapons systems determines where the limited available funds will be spent. It is true that futuristic push-button warfare can be financed to the expense of cutting back conventional weapons; however, usually history has been such that sufficient funds are not available to conduct both and compromises always result. It is a job of the military leaders to determine which area must be funded to the exclusion of the other.

Between World War I and World War II the War and Navy Departments built a number of important new research installations. These were built to work exclusively on problems for National Defense. During World War II, many new organizational arrangements were carried out for the express purpose of conducting military research and developments. The first of these was the Office of Scientific Research and Development (OSRD) and its major constituents the National Defense Research Council (NDRC) and the Committee on Medical Research and the Manhattan Engineering District of the War Department's Corps of Engineers, which took over the research and development programs on nuclear fission.

From 1939 to 1946, the NRDC and the OSRD became full-time partners of the military program and almost completely dominated the field of military research and development.

At the termination of World War II, the general public had a popular understanding and acceptance of science, research and development, and so forth -- these stood at an all time high. As a result of wartime accomplishments, science enjoyed an unprecedented prestige; however, there was a very severe problem facing the civilian scientist. Most of these men were anxious to return to their peace time pursuits and in 1945, the Office of Scientific Research and Development began to disband. From the National Defense point of view, however, it must be pointed out that many of the projects that had been carried on were projects which would be required for further development and utilization in the post-war period. Therefore, the military departments undertook the job of preserving these facilities and at least the corps and nucleus of personnel engaged in these essential projects.

There has been much published and it was widely recognized that wartime weapon developments had drawn heavily on the basic knowledge produced by research in earlier years. Some of the problems facing the War Department were met by transferring a number of the OSRD projects to the military departments for instance, and the Air Force integrated personnel and equipment of the Radiation Laboratory at the Massachusetts Institute of Technology into the Air Research and Development Command, Cambridge Research Center. Unforeseen difficulties

developed in the process of obtaining adequate level of support of basic research. In 1945, Dr. Vannevar Bush, a wartime director of OSRD, submitted a report at the request of President Franklin D. Roosevelt on the steps needed to continue the nation's scientific advance. In his widely publicized report, Science -- The Endless Frontier, Bush proposed the establishment of the National Research Foundation to support the research and education in science and dissemination of scientific information.

The principal federal support for basic research in the years immediately following the war came from the Navy Department which set up the Office of Research and Inventions in 1945. In 1946, by Act of Congress, this became the Office of Naval Research which supports basic research in the many scientific fields of interest to the Navy. Another major source of support for such research was the National Institute of Health. From the Atomic Energy Commission, an agency also established in 1946, came other funds for the support of basic research.

From 1946 to 1950, the relationship between the scientists and the military was such during this period that the civilian program was replaced by a more limited program operated by the military services, with the civilian policy direction being exerted by the Research and Development Board of the Department of Defense. The Research and Development Board was to advise the Secre-

tary of Defense and to allocate research and development responsibility among the military services, but it had no power to initiate research and development itself.

MAJOR DEVELOPMENTS IN THE FEDERAL ORGANIZATION FOR SCIENTIFIC ACTIVITIES SINCE 1947

In 1947, President Truman, recognizing the need for a full examination of the Nation's scientific research effort, established an Adhoc Body, the President's Scientific Research Board, under the chairmanship of his advisor, Dr. John R. Steelman.[3]

A review of the history of the Federal Government's scientific research effort reveals certain characteristics of the development which provide a useful background from analysis of experience both past and present.

Many government agencies had broadened the scope of their scientific work. Civilian agencies assumed scientific functions which had originated in the military departments. In many instances a military department would be the first to undertake a scientific function. Subsequently these functions were turned over to civilian agencies after the ground was broken and a wider civilian application of the work became evident.

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3. (NSF-56-17), Op. cit., p. 4.

Major wars spurred the creation of new governmental and quasi-governmental agencies to aid in military research. For example, in the Civil War the quasi-governmental National Academy of Science was established for this purpose. In World War I, the National Research Council was established. Before World War II, President Roosevelt established the National Defense Research Committee to concentrate the scientific resources of the country on weapons research. In 1941, the Office of Scientific Research and Development was created under the leadership of Dr. Vannevar Bush to provide a broader organization to "serve as a center of mobilization of the scientific personnel and resources of the nation in order to assure a maximum utilization of such personnel and resources in developing and applying the results of scientific research in defense purposes.[4]

The number and variety of government laboratories multiplied. The government concentrated its efforts primarily on applied research in the 19th and early 20th centuries, and a large proportion of the scientific and technical personnel in the government were engaged in large-scale data-gathering operations. Surveys were made of the Nation's research effort. The National Resources Committee's comprehensive survey of the nation's research effort (Research, A National Resource, 1938) was a one time inquiry lacking the means

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4. Ibid., p. 5.

of sustained follow-up of the problems which it cited as calling for governmental attention. In 1934, President Roosevelt established a Scientific Advisory Board to report on the status of the Federal Government Scientific Programs. This organization did not live long as its first recommendation called for an increase in Federal research expenditures -- these were not implemented.

In 1947, science had come to occupy an important part of the Federal Government's activities with a considerable portion of Federal personnel engaged in research and development in a large number of laboratories. In 1947, the President's Scientific Research Board undertook a study of the Federal Government Scientific programs to examine the question of scientific organization, personnel and resources. The report of the board's chairman, entitled "Science and Public Policy", recommended among other things dealing with the government organization for science as follows:[5]

1. An inter-departmental committee for science research and development be established.
2. A unit be set up in the Bureau of the Budget to review Federal Scientific Programs.
3. A White House Staff member be designated by

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5. Ibid., p. 6.

the President for purposes of scientific liaison.

4. A National Science Foundation be established in the Executive Office of the President.

Other recommendations dealt with departmental organization for the conduct of science activities.

In the years since 1947 a number of significant changes have occurred in the organization of the Federal Government for scientific activities. New agencies with important scientific responsibilities have appeared. Several existing agencies have undergone reorganization, with the step by step evolution of organization for research and development in the military departments being of considerable importance.

From 1950 to the present time, the scientists and military have achieved a degree of separation of actual research and development operations from direct military conflict with science. This is accomplished by the use of projects or weapons systems. For example, some projects are permitted to operate either individually by one service or funded jointly by several of the services to an organization outside of the Department of Defense. The military services provide specifications, funding, and design characteristics to which the university, private industry, or non-profit organizations conduct their research and development. During the Riehlman

Committee hearings it was stated:

> In 1950 the Navy realized that with the widespread introduction of the snorkel submarine, and with the eminent introduction of the nuclear submarine or of the hydrogen-peroxide powered submarine, the anti-submarine problem was getting completely out of hand. With great wisdom, Admiral Sherman, then CNO, asked the Massachusetts Institute of Technology to organize the Hartwell project. Under this project, the Navy requested that a group of scientists representing every conceivable related scientific discipline be brought together to investigate the entire problem of maintaining transport over the seas. The Navy asked that this be done without limitations by preconceived ideas, but that rather the whole potentialities of science be explored to determine whether in some way we could regain control of the submarine. The project was organized with scientists of very wide experience and from many disciplines. These scientists were thoroughly briefed on the entire strategic situation as it related to control of the seas, and no relevant information was withheld. Moreover, even when the scientist believed that they needed information that the Navy thought irrelevant to the situation, they were given this information.[6]

Similar projects in science have been established at M.I.T. and other universities. Also extensive research and development is conducted in military directed and managed research and development laboratories, in military laboratories managed by private industry or universities, and in laboratories conducting limited area projects on a contract basis either with the government

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6. Op. cit., p. 633.

or as a sub-contractor to private industry or a university.

Department of Defense

The organization of the Department of Defense has been in a state of flux and is still in a state of flux. Since 1947 a series of major changes have taken place in the organization of military research and development.

Immediately after World War II, the Office of Scientific Research and Development was disbanding. This is the organization that had done the majority of the research and development conducted for the military services during the war.

In 1946, the Secretary of War and the Secretary of Navy established the Joint-Research Development Board composed of two representatives of each department and a chairman, Dr. Vannevar Bush.

In 1947, the National Security Act established the Office of the Secretary of Defense and the Department of Air Force.

Secretary of Defense

The Secretary of Defense was given broad responsibilities for affecting the unification of the activities of the three military departments. The duties and mission of the Assistant Secretary of Defense for Research

and Engineering is included as Appendix 1.

Research and Development Board

Prior to the establishment of the Assistant Secretary of Defense for Research and Development and the Assistant Secretary of Defense for Engineering, the Secretary of Defense felt the need for a staff to assist him and to advise him on the status of research and development activities within each of the military departments: the Army, the Air Force and the Navy. The author of this paper was a panel member of the Research and Development Board until it was disbanded. The mission of the Research and Development Board included the preparation of an integrated military research and development program, rendering advice on trends in scientific research of relevance to National Defense in recommending measures of inter-service coordination and allocation of responsibilities. The number of civil service employees and military representatives from each of the three services numbered only several hundred.

However, to supplement the efforts of the permanent staff, over 2,000 consultants were assigned to committees and panels. Usually the committees were composed of military and civilian representatives from the three military departments and frequently members from private industry who were hired as consultants. From personal experience I would say that the committees and

panels exchanged communications very well on the status and review of scientific programs in each of the services. The Research and Development Board, based upon recommendations from the committees and panels, furnished staff reports to the Secretary of Defense. From the position of a junior engineer at that time, it appeared to this writer that the reports were frequently very accurate and true; however, each military department always had the feeling of "not invented here" or "what would be gained to our or his specific organization if such an action was taken." It has been reported that in the first years of unification the Research and Development Board performed a particularly useful function providing a quorum for the reconciliation of the diverse viewpoints of the three services and for the exchange of information on activities of common concern.[7]

In 1953, the President's Advisory Committee on Government Organization (the Rockefeller Committee) recommended the abolishment of the Research and Development Board to the Congress. This recommendation from the Rockefeller Committee recommended the establishment of an Assistant Secretary of Defense for Research and Development and an Assistant Secretary of Defense for Applications Engineering. The latter organization changed its name during the latter part of 1956 to the

7. (NSF 56-17), Op. cit., p. 9.

Assistant Secretary of Defense Engineering. In February, 1957, this office combined with the Assistant Secretary of Defense for Research. The new title is Assistant Secretary of Defense for Research and Engineering. (See Appendix 1.)

The commission on organization of the Executive Branch of the Government (Hoover Commission) in its report of June, 1955, made several recommendations aimed at "better integration and stronger administration in the Office of the Secretary of Defense" which have a bearing on organization for research and development.

Department of the Army

At the end of World War II some important organization changes took place in the War Department. The most important of these possibly was two years after the close of World War II -- the Air Force achieved complete independence from the War Department. The creation of a separate Department of Air Force removed from the Army the organization which had accounted an appreciable portion of all pre-war and wartime research and development expenditures.

Department of the Navy

In the Department of the Navy, each Bureau emerged from the War still responsible for research and development in its own field of cognizance.

In 1954, the Secretary's Committee on Organization of the Department of the Navy (Gates Committee) recommended that the Office of Naval Research resume responsibilities for coordination of the Navy's Research and Development Program. In June, 1954, a directive of the Secretary of the Navy implemented this recommendation.

The Chief of Naval Research (ONR) has also been responsible since the beginning of fiscal year 1955 for the submission of budget estimates of all Navy Department Research and Development Programs under a single appropriation heading. A committee chaired by the Assistant Secretary of Navy for Air was set up in 1955 to coordinate various functions of research and development common to the Bureaus. The Hoover Commission declared in its report that the Navy Department has not gone far enough in the direction of separating research and development from the normal duties of the Assistant Secretary of Navy.

Department of the Air Force

The organization of the Department of the Air Force for the conduct of its research and development was naturally influenced by the organization structure which it inherited from the Army Air Force.

Most supporting activities other than research and development were lodged in the Air Material Command,

whose primary functions were procurement, supply and maintenance. The Command contained both a Directorate for Research and Development and a Directorate for Material, the latter being by far the larger organization.

In 1951, research and development was accorded separate organizational status, with the establishment of the Air Research and Development Command. Its headquarters was originally located at Wright Air Force Base in close proximity to the Headquarters Air Material Command, but after a short time it was transferred to Baltimore, Maryland. From current publicity in the Washington papers and from rumor sources throughout the Department of Defense, it is anticipated that the Headquarters of the Air Research and Development Command will be transferred to Washington, D. C. within two years.

In 1950 the Secretary of the Air Force appointed a special assistant (for research and development) who assumed responsibilities for research and development matters coming to the Secretarial level. In 1954, the Department of the Air Force became the first of the three military departments to establish a position at the Secretarial level devoted exclusively to research and development. The Hoover Commission in 1955 congratulated the Department of Air Force for appointing the First Secretary of Air Force (Research and Development), a person experienced in scientific administration. In August,

1955, a former director of Bell Laboratories, Mr. Donald Quarles, who had more recently been Assistant Secretary of Defense for Research and Development was made Secretary of Air Force.

Contractor-Operated Research Centers

Since 1947 each of the three military departments has made extensive use of an organizational device first used by the Office of Scientific Research and Development during World War II -- the contractor-operated center, usually in facilities which the government owns.

While these centers vary widely in the nature of their management control and the scope of their mission they all have one thing in common -- a primary contractual relationship with one or more of the military departments. This new and steadily growing arrangement has been particularly well-suited to research in broad problem areas associated with weapon systems development. Each military department has also used such centers for the conduct of operations research.

By 1955 there were roughly two dozen such research centers engaged almost entirely on work for the three military departments. The nature of the contractual arrangements between the military departments and the universities, other non-profit organizations or commercial concerns operating the centers enable the directors to carry out their programs free from many of

the administrative problems posed for scientific work by government procedures and organizations.

NAVY RESEARCH AND DEVELOPMENT COMMAND INSTALLATION AND CONTRACTOR-RESEARCH CENTERS

Office of Naval Research

The office of Naval Research has four contractor-operated research centers. They are: Operations Research Group, Naval Oceanographic Research Laboratory, Naval Biological Laboratory and Arctic Laboratory.

The Office of Naval Research has three military installations. These are: The Naval Research Laboratory; the Underwater Sound Reference Laboratory; and Special Devices Center.

The Bureau of Ordnance

The Bureau of Ordnance currently has five contractor-operated research centers. They are: The Applied Physics Laboratory, Silver Springs, Maryland; The Ordnance Aerial Laboratory; The Ordnance Research Laboratory; The Allegheny Ballistic Laboratory; and The Applied Physics Laboratory, Seattle, Washington. The Naval Bureau of Ordnance currently has ten research and development laboratories which are considered military installations working totally or partially for the Bureau of Ordnance. They are: The Naval Ordnance

Laboratory, Corona, California; The Naval Ordnance Plant, Indianapolis, Indiana; the Naval Proving Ground, Dahlgren, Virginia; The Naval Powder Factory, Indianhead, Maryland; The Navy Gun Factory, Washington, D. C.; The Naval Ordnance Laboratory, White Oak, Maryland; The Naval Ordnance Missile Test Station, Pt. Mague, California; The Naval Ordnance Underwater Station, Newport, Rhode Island; Naval Ordnance Test Station, Inyokern, California; The Naval Aviation Ordnance Test Station, Chincoteague, Virginia.

The Bureau of Aeronautics

The Bureau of Aeronautics does not have any contractor-operated facilities.

The Bureau of Aeronautics has eight military installations. They are: The Naval Air Missile Test Center; The Naval Air Test Center; The Naval Air Rocket Test Station; The Naval School of Aviation Medicine; The Naval Air Materials Center; The Naval Parachute Unit; The Naval Air Development Center; and The Naval Air Turbine Test Station.

The Bureau of Ships

The Bureau of Ships has no contractor-operated laboratories or scientific installations.

The Bureau of Ships has eleven scientific installations of the military type. They are: The U. S.

Navy Underwater Sound Laboratory; The David Taylor Model Basin; The U. S. Navy Mine Countermeasures Station; The U. S. Navy Radiological Defense Laboratory; The U. S. Navy Boiler and Turbine Laboratory; The U. S. Navy Engineering Experimental Station; The U. S. Navy Electronics Laboratory; Materials Laboratory, New York Navy Shipyard; The Industrial Test Laboratory, Philadelphia Navy Shipyard; The Rubber Laboratory, Mare Island Naval Shipyard; and The Underwater Explosions Research Division, Norfolk Naval Shipyard.

AIR RESEARCH AND DEVELOPMENT COMMAND INSTALLATIONS AND CONTRACTOR-OPERATED RESEARCH CENTERS

The Air Research and Development Command has nine contractor-operated research centers. They are: Aircraft Nuclear Power Plant Facilities, Aircraft Nuclear Test Facilities, Boston University Physical Research Laboratory, Chicago MidWest Laboratory, Cornell Aeronautical Laboratories, Engineering Research Institutes of the University of Michigan, Arnold Engineering Development Center (ARO), Project Doan Brook and Project Lincoln.

The Air Research and Development Command's installations under military control are: Air Force Armament Center, Air Force Cambridge Research Center, Air Force Flight Test Center, Air Force Missile Test

Center, Air Force Office of Scientific Research, Air Force Personnel and Research Center, Air Force Special Weapons Center, Holloman Air Development Center, Arnold Engineering Development Center, Rome Air Development Center, Wright Air Development Center and Armed Services Technical Information Agency.

DEPARTMENT OF THE ARMY ORDNANCE CORPS INSTALLATIONS AND CONTRACTOR-OPERATED RESEARCH CENTERS

The Army Ordnance Corps has three contractor-operated research centers. They are: The Jet Propulsion Laboratory, Rocket and Propellant Laboratory, and The Thiokol Project.

The Army Ordnance Corps has eight military installations under the coordinated command of the Assistant Chief of Ordnance for Research and Development. These military installations are: Office of Ordnance Research, Aberdeen Proving Ground, Diamond Ordnance Fuze Laboratory, White Sands Proving Ground, Frankport Arsenal, Picatinny Arsenal, Redstone Arsenal and Watertown Arsenal.

The Department of the Army Transportation Corps, Signal Corps, Quartermaster Corps, Chemical Corps, Corps of Engineers and other departments of the Department of the Army may have contractor-operated research Laboratories, but this author has been unable to obtain

information confirming or denying this fact.

ATOMIC ENERGY COMMISSION CONTRACTOR-OPERATED CENTERS

The Atomic Energy Commission has seventeen research centers operating under the AEC. They are: The Ames Laboratory, the Argonne Cancer Research Hospital, Argonne National Laboratory, Atomic Energy Project University of California at Los Angeles, Atomic Energy Project University of Rochester, Bettis Plant, Brook Haven National Laboratory, Knolls Atomic Power Laboratory, Los Alamos Scientific Laboratory, Mound Laboratory, Materials Testing Reactor, National Reactor Testing Station, Oakridge Institute of Nuclear Studies, Oakridge National Laboratory, Radiation Laboratory, Radiological Laboratory and Sandia Laboratory.

The Atomic Energy Commission depends upon a large number of industrial contractors for the execution of its major programs, and only incidentally engages in the actual conduct of research and development and other scientific activities. A sizeable proportion of the total scientific effort of the Commission is conducted in "Research Centers" -- facilities owned by the Commission, but operated by industrial concerns, universities, and in two instances non-profit corporations.

Considerable funds from the Atomic Energy Commission are channeled through the various organiza-

tions of the Department of Defense to produce the non-atomic portions of atomic weapons and/or other hardware items desired by the Atomic Energy Commission. In addition, the Department of Defense channels funds directly to certain atomic weapons research.

DEPARTMENT OF THE ARMY

The Department of the Army[8] engages in a variety of scientific activities which include the conduct of research and development and the planning and administration related thereto, the collection of scientific data, and the training of scientific manpower. The Army's current annual rate of expenditures for research and development, exclusive of other scientific activities is $350 million. This sum approximates 3½ per cent of the total Army budget during the fiscal year 1954. Usually the management of the department's major research and development programs is delegated to the seven technical services: Army Medical Services, Corps of Engineers, Transportation Corps, Chemical Corps, Ordnance Corps, Quartermaster Corps and Signal Corps. Within their areas of responsibilities they plan and administer research and development programs in support of their primary functions. The one exception of this rule is that the Ord-

8. National Science Foundation, NSF. 56-17, "Organization of the Federal Government for Scientific Activities", U. S. Government Printing Office, Washington: 1956, p. 113.

nance Corps Office of Ordnance Research administers the Army's over-all basic research program. The Army conducts its "in house" research in scientific facilities located within large Army establishments (arsenals, proving grounds, training centers, hospitals, and so forth). In a number of cases recently, separate facilities have been set apart physically from other activities, and in some cases the Army has taken over or established completely new integrated facilities.

Under contract arrangements, industries, universities and other government agencies play an important role in the conduct of research in the Army. Some of the Army's research programs are performed in research centers which are usually, but not always, owned by the government and operated by contractors.

FUNDS[1] AND PERSONNEL[2]

Army Funds Applied in Fiscal Year 1954

Total for all activities	$9,517,784,000
Applied to scientific activities	$583,962,000

1. These financial figures exclude working, revolving and special funds and expired general appropriations.
2. The personnel figures exclude all military personnel, and includes all wage board personnel.

Personnel as of August 31, 1954:

	In Scientific Activities	All Other Activities
Scientific	9,160	22,594
All Other	33,369	412,712
Total	42,529	435,306

DEPARTMENT OF THE NAVY

The Department of the Navy[9] was established by Act of Congress in 1798. It was incorporated in the National Military Establishment by the National Security Act of 1947, and became a separate department of the Department of the Defense, when the National Military Establishment was so redesignated by the National Security Act as amended in 1949. The mission of the Department of the Navy is to maintain the Navy and Marine Corps as a part of the Department of Defense in sufficient readiness to fulfill its responsibility as set forth in the National Security Act of 1947 as amended, and in the "Functions of the Joint Chief of Staffs", issued by the Secretary of Defense on April 21, 1948. From this fundamental mission evolve four (4) basic tasks of functions, policy control, naval command, logistics administration and control and business administration. The Secretary of the Navy exercises general supervision over all

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9. Ibid., p. 157.

Naval affairs while delegating certain responsibilities to his principal civilian and naval assistants.

Scientific Activities

The Navy Department engages in a variety of activities which include the conduct of research and development, the planning and administration related thereto, and the training of scientific manpower. Naval Research and Development programs range from basic research in the many sciences, Navy Technology through the development and testing of end-items, and techniques for operational use. The Navy's current annual rate of expenditures for research and development exceeds $450 million. This sum approximates four per cent of the total Navy Budget.

Management of the department's many major research and development programs, with the exception of those directly administered by the Office of Naval Research, is delegated to the seven technical bureaus. Most of this work is done by the Bureau of Ordnance, by the Bureau of Aeronautics and the Bureau of Ships. The Bureaus plan and administer research and development programs in support of their primary missions. In addition, the Bureaus administer or conduct research and development for the Marine Corps.

The technical Bureaus carry out much of their research and development in Naval Laboratories, under

the cognizances of each technical Bureau and under the Office of Naval Research. In some instances research and development facilities are located within large Naval establishments such as shipyards and air stations.

Under contract arrangements, industries and other government agencies play important roles in the conduct of research for the Navy. Some of the Navy's research programs are performed in research centers, which are usually, but not always, owned by the government and operated by industrial and university contractors.

FUNDS AND PERSONNEL

Navy Funds Applied in Fiscal Year 1954

Total for All Activities	$8,258,236,000
Applied to Scientific Activities	$525,944,000

Personnel as of August 31, 1954:	In Scientific Activities	In All Activities
Scientific	9,720	18,062
All Other	24,811	361,504
Total	34,531	397,566

The Assistant Secretary of Navy (Air) has for several years been responsible for the supervision for

all the department's research and development activities. The recent establishment of an Assistant Secretary (personnel and reserve forces) freed the former official from time-consuming duties connected with military personnel, permitting him to devote a substantial part of his time to research and development matters.

The Assistant Secretary of Navy (Air) has the Navy Research and Development Committee to assist him in review and supervision of programs. Its members include the Chief of Naval Research and officers primarily concerned with research and development in the office of the Chief of Naval Operations, the Commandant of the Marine Corps, and each of the Bureaus. The Assistant Secretary for Air chairs this committee.

The Chief of Naval Operations is responsible for determining the requirements of the operating forces and directing the Bureaus in fulfilling these requirements, and carries out his responsibilities for research and development programs through the Deputy Chief of Naval Operations.

The Naval Research and Development Review Board is chaired by DCNO and is made up of officers from the staff of DCNO and DCNO Air, DCNO Logistics, the Chief of Naval Research, and the Assistant Chief of Staff, G-4 Headquarters, Marine Corps. This Board formulates the planning objectives which form the basis for Naval Research and Development Plan, and submits it

through the Chief of Naval Operations to the Assistant Secretary of Navy (Air) for approval. The Board reviews priority classification of Research and Development projects, recommends guide lines for each fiscal year, and reviews the allocation of funds to Research and Development projects. It submits to the Chief of Naval Operations each fiscal year a coordinated program for forwarding for the approval of the Assistant Secretary of Navy (Air) via the Chief of Naval Operations and the Research and Development Committee.

The Chief of Naval Research is responsible for the coordination of all Navál Research and, by the Secretarial directive of June, 1954, for the technical coordination of development. The latter program is now an active and integral part of the office of Naval Research's over-all function.

The Naval Research Advisory Committee, composed of fifteen eminent civilian scientists, advises the Chief of Naval Operations and the Chief of Naval Research on the trends and potentialities of research relating to Naval Operations and on the administration of departmental Research and Development programs.

Each Bureau conducts Research and Development on subjects over which it exercises cognizance, in establishments under its management control, and on contract. Each Bureau has an Assistant Chief or a Division Director who exercises principle responsibility for

Bureau research programs. Most of the bureaus make fairly extensive use of the committees in the scientific and industrial world.

In the field laboratory, considerable use is made of Laboratory Committees, composed of top ranking scientists employed at each Laboratory in planning and coordinating the Laboratory programs.

THE DEPARTMENT OF THE AIR FORCE

The Department of the Air Force[10] was established as a part of the National Military Establishment by the National Security Act of 1947 and became a department within the Department of Defense when the National Military Establishment was so redesignated by the National Security Act as amended in 1949. The achievement of departmental status by the Air Force marked the culmination of an evolutionary development beginning with the establishment in the Signal Corps of an Aeronautical Division in 1907, followed by the progressive elevation of military aviation within the War Department to Corps status in 1918 and Force Status in 1941. The Air Force has primarily responsibility for defending the United States against air attack; for gaining and maintaining general air supremacy; for defeating enemy air forces;

10. Ibid., p. 197.

for formulating joint doctrine and procedures, in coordination with the other services; for the defense of the United States in air attack; for providing the necessary units, equipment, and facilities for strategic air warfare; for providing Air Force units for joint amphibious and airborne operations; for furnishing close combat logistical air support to the Army; and for providing air transportation for the armed services, except as otherwise assigned. The Secretary of the Air Force exercises general supervision over all Air Force affairs while delegating certain responsibilities and military assistance.

Scientific Activities

The Department of the Air Force engages in the gamut of scientific activities which includes the conduct of research and development, the planning and administration related thereto, scientific information, and the training of scientists. The major missions set forth above are administering programs which range from basic or "blue sky" assuring long range advances in aeronautical and related sciences to the development and test of aircraft, missiles, and related equipment for operational use by the combat support and service units of the Air Force.

The current annual rate of expenditure for Research and Development by the Air Force is roughly

$600 million. This sum represents three per cent of the total budget of the Air Force.

In contrast to the other two services, the Air Force has placed the management of all its major Research and Development programs under a single command. The Air Research and Development Command is composed of a Headquarters located at Baltimore (soon to be moved to Washington, D. C.) and more than ten field centers. This organization, through its field centers, also coordinates its program (especially throughout the development testing cycle for new systems, equipment, and techniques) using all the commands of the Air Force.

Each of the centers conducts "in house" research and/or testing programs. The Air Force carries out the preponderance of its Research and Development Programs, however, by contract with universities, research centers, and other government agencies.

FUNDS AND PERSONNEL

Air Force Funds Applied in Fiscal Year 1954

Total for all activities	$9,752,374,000
Applied to Scientific Activities	$736,554,000

Personnel as of August 31, 1954:

	In Scientific Activities	In All Activities
Scientific	3,780	7,844
All Other	16,003	246,885
Total	19,783	254,729

CHAPTER IV

FUNDING OF RESEARCH AND DEVELOPMENT

Funding of Research and Development; Science and Engineering in American Industry; Expenditures by the Large Private Foundations; Research by Cooperative Organizations; Research and Development by Non-profit Research Institutes and Commercial Laboratories, Fiscal Year 1953; Commercial Laboratories (history); Commercial Laboratories Research and Development Expenditures 1953; Research and Development in Private Industry; Federal Funds for Science, Fiscal Years 1955, 1956, and 1957; Applied Research - Basic Research in the Government; and Federal Research and Development Trends.

SCIENCE AND ENGINEERING IN AMERICAN INDUSTRY

It is interesting to note that for the years 1953 and 1954, the research and development cost estimates for private industry totaled $3,664,000 in 1953 and $4,089,000 in 1954. This represents a 11.6 per cent increase in expenditure by private industry between 1953 and 1954.[1] However, it has been estimated that the total industrial expenditures, part of which were financed by the governmental communities, were over $1.6 billion in

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1. National Science Foundation, NSF 56-16, "Science and Engineering in American Industry", Final Report on a 1953-1954 Survey, U. S. Government Printing Office, Washington; 1956, p. 3.

1953.[2]

It is obvious that the spending by the Department of Defense and other parts of the Federal Government has had an extremely important part in the growth of industrial research. It has been estimated that well over 60 or 70 per cent of the companies doing research and development work have contracts with the United States Government. In many cases companies feel that it is their patriotic duty and they must perform this government work. In most cases companies use many of their top technical people to work on government research contracts. There is a feeling among some industrial representatives today that as a long term policy they would desire to do less government research and development work except in cases where the product being researched is a direct application to the product line normally manufactured, sold and distributed by the company concerned.

Most companies feel that by accepting government work their company benefits from the general know-how that is being developed; the company benefits from the accumulation of technical personnel with broader experience and more of an understanding of coordinating and management details; and in general a much broader

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2. DeWitt C. Dearborn, "Industrial Development Spending", (1951-1952), Harvard University, Graduate School of Business Administration, p. 46.

person results in the company as a result of having managed a governmental contract than if this individual had remained in his normal billet in the company. This does, however, present a problem for nearly all companies conducting research on large projects. Their top technical personnel are taken out of their normal slots in the company organization and moved over to the government laboratory or to manage the laboratory owned by the government but being administered and managed by the contractor. These jobs normally place the individual two steps above his old billet in the old company. He is promoted immediately to have pay commensurate with the duties he is performing. This creates a very undesirable situation. In effect it creates a situation where the word gets around to all other employees that the best way to get ahead in our own company is to work for our own company at a government laboratory -- one gets ahead faster this way.

The actual loss to the organization, company or corporation is that during the few years the individual has been working exclusively on government contracts he has been unfamiliar with the details on the day to day operations of his own company and in general, he has broadened his own base of experience and knowledge to the point where he will not return to the original job he had. This presents the company with a problem of observation, management policy, training policy and

morale situations.

All companies that do not have government contracts feel that this would be an excellent way of broadening their outlook on things other than in their own immediate product, and they feel that a government contract would put them in a position to handle work of a different nature from that which they now handle. Usually this type of company feels that a completely unrelated field is fine since it gives the company diversification and they hope in the long run will put them in an active competitive field in an unrelated industry from that which they are now in. Private industries and universities do not lose the patent rights that they obtain while conducting research on government contracts. Numerous companies have stated that any civilian applications we get out of working on contracts for the government are completely ours. A question which has become very common throughout our private industry laboratories, university laboratories and government laboratories is, "With the lack of engineering graduates, management-trained administrators and policy-makers, where do we go from here?"

The shortage of engineers and scientists puts a continuing and real pressure on the government's laboratories to maintain a nucleus of qualified engineers, scientists, managers and administrators, both military and civil servants, capable of handling the coordination,

planning, programming and scheduling of all necessary projects in the event that it became popular or necessary for the private industries and universities to place emphasis on their primary purposes and de-emphasize the government contracts. It has been stated that one of the most significant facts of the current status of industrial research is that the change which is appearing is a significant increase in the number of companies employing research staffs of five or less. If each of the 100,000 manufacturing concerns of consequence employed only one additional research worker this would increase by one-third our present research effort in private industry. In 1900, there were 30 engineers per 10,000 industrial workers; in 1953, there were almost 200 engineers per 10,000 industrial workers. The expenditure for the support of research workers varies from $16,000 in the chemical and allied products to $68,600 in the motor vehicle industry. As the trend toward research staffs continues, the industrial research director is stimulated to operate more efficiently and to bring low cost and better operations through greater and more efficient use of supporting personnel. And it can be concluded that without current continued increases in research operations, industrial investment can only continue to go up.

SCIENTIFIC RESEARCH EXPENDITURES BY THE LARGER PRIVATE FOUNDATIONS

A study of the larger American privately-endowed foundations reveals the most surprising fact that a relatively small amount of money was spent to obtain significant achievements.[3] The foundations, with many interests in addition to scientific research, have altogether only about four per cent of the total philanthropic dollar to spend. It was felt by these foundations that the considered and imaginative investment of small sums may accomplish great purposes.

In 1953, the scientific research supported by private foundations covered almost every field of research; the total amount spent was certainly a minor part of the total expenditure for scientific research. The 77 largest endowed foundations spent only $26 million out of an expenditure on research and development of approximately $5 billion. It was reported that the majority of this money was for the support of scientific research in areas which are critical for further progress. For the purposes of this report, a foundation has been defined as "a non-governmental, non-profit organization having a principal fund of its own, managed by its own

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3. National Science Foundation, "Scientific Research and Expenditures by the Larger Private Foundations", U. S. Government Printing Office, Washington, 1956, 21 pp.

trustees or directors, and established to maintain or aid social, educational, charitable, religious or other activities serving a common welfare."

Based upon data obtained by the American Foundation Information Services as a result of a search of the Internal Revenue Service reports, it is estimated that there are between 4,000 and 4,500 foundations in the United States today. The Ford Foundation appears to rank the highest with $520,232,000 of ledger value. The Rockefeller Foundation is number two with $318,229,000 market value. The Carnegie Corporation of New York is third with $196,007,000 market value. Number four is the Kellog (W. K.) Foundation with $109,812,000 market value. Number five is Duke Endowment with $108,000,000 ledger value. Number six is the Pew Memorial Foundation; number seven is the Commonwealth Fund; number eight is the Kresge Foundation; number nine is the Board of Directors of City Trust (Philadelphia); number ten is the Carnegie Institution of Washington; number eleven is the Rockefeller Brothers Fund; etc. A complete listing of the 77 largest foundations in 1953 with the assets and income assets of each of the firms is available in the National Science Foundation Study, pages two and three.[4]

The 77 largest foundations have assets totaling $3 billion and in 1953 the income from these assets was

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4. Ibid., p. 2 and 3.

$166,000,000. This is an approximate figure of four per cent income on the market value of their securities.

As can be noted from the paragraph above, the three largest foundations -- the Ford Foundation, the Rockefeller Foundation, and the Carnegie Foundation of New York -- have combined assets of over $1,000,000 which represent approximately 34 per cent of the assets of all 77 foundations and the income of the largest three represents $73.4 million or more than 44 per cent of the income of the largest 77.

Approximately ten per cent of all funds earned were allocated for administrative and miscellaneous expenses leaving only $142,000,000 to be spent on programs or just under 90 per cent of their earned income was spent.

Of the $142,000,000 which was spent during 1953, only $26,000,000 was spent for scientific research and development and this represents approximately 16 per cent of the total expenditures of these foundations. This compares with the total or scientific research in 1953 of approximately $5,000,000,000, of which more than $2,000,000,000 was spent by government agencies. In other words the total contribution from the largest foundations to scientific research ($26,000,000) is in fact less than one per cent of the money spent that fiscal year.

An interesting comparison of the growth of the

physical sciences research and development included in the above figures is that in 1939 the physical sciences accounted for less than one-tenth of the expenditure by these foundations, whereas in 1946 this figure had tripled in dollar expenditures as its percentage of the total. And in 1953, the total research expenditures were over double the 1946 expenditures being in the order of $23 million and in this case the physical sciences dropped in dollar amounts below the 1946 record for a total of only 1.6 per cent of the total expenditures by the 77 largest foundations. Further it would be noted that the research and development portion of the total had dropped below 20 per cent. This included medical and biological sciences in addition to physical sciences.

Most of the tremendous expenditures in research in the United States in the past decade have been in applied and developmental experimentations rather than in basic research.

The distribution of funds from scientific research of 77 larger foundations were approximately as follows: colleges and universities received 47 per-cent; other agencies 23 per cent; health agencies and independent hospitals ten per cent; reporting foundations (staff research) 14 per cent; and individuals six per cent. At present only a small group, chiefly the larger and older foundations, support scientific research with any substantial portion of their funds. It

is not certain that they will maintain their present small proportion of scientific research funds in the United States. There is strong indication that these funds may be spent for scientific research outside of the United States.

It has been reported that there may be approximately 4,500 foundations total. Reliable figures on the expenditures on all foundations are not available, but indications and best estimates put this total at approximately $300,000,000. As stated earlier, the 77 largest foundations spent $164,000,000; therefore, $136,000,000 represents the smaller foundations from which they may possibly have spent as much as five per cent, or $6.8 million for scientific research, chiefly medical. Therefore, as far as the research and development in the physical sciences are concerned this effort by the smaller foundations has no significance at all.

RESEARCH BY COOPERATIVE ORGANIZATIONS

Cooperative organizations, as herein defined, include trade associations, professional and technical societies, agricultural cooperatives, research-educational cooperatives, and "other cooperative groups".

A Survey of Scientific Research by Trade Associations, Professional and Technical Societies and Other Cooperative Groups,[5] determined that there are a total

5. National Science Foundation, NSF 56-12, "Research

of 543 cooperative organizations supporting research and development. It is estimated that these 543 organizations spent $21,152,200 for research and development in 1953.

A total of 173 organizations supported $17,902,400 for technical research and development. Therefore, in effect only 173 organizations support the biggest majority of all funding.

The figures indicate that 70 per cent ($12,568,400) of the total amount spent on technical research and development was spent on applied research and development and the remaining 30 per cent ($5,334,000) was invested in basic research predominantly in the engineering and the chemical sciences.

Approximately 53 per cent of the total research and development funds of the 173 organizations was spent in laboratories belonging to the organizations. Therefore, a total of approximately 66 organizations operated industrial-type research laboratories employing 696 scientists and engineers. It was reported that the government regulatory agencies had little apparent effect upon cooperative organizations. And it was further stated that technical research and development by government agencies is supplemental to the research carried out by these cooperative organizations or in

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by Cooperative Organizations", U. S. Government Printing Office, Washington: 1956, 47 pp.

addition to the cooperative organization effort.

RESEARCH AND DEVELOPMENT BY NON-PROFIT RESEARCH INSTITUTES AND COMMERCIAL LABORATORIES, FISCAL YEAR 1953

A survey of the research and development activities of non-profit research institutes and commercial laboratories indicates that the majority of the commercial laboratories and non-profit research institutes in the United States were organized after 1941,[6] due primarily to the expansion of the research program of the Federal Government. Since World War II, the military financing of these organizations provided an important segment of the work of many, if not most, of all such research organizations of any substantial size. Both the industrial laboratory and the non-profit research institutes were designed primarily to solve business problems. And in general there appears to be little distinction between the character, history, and activities of these various organizations. It appears that to manage, administer, etc., such research organizations an advanced academic degree is a prerequisite and in general, experience and background in research and ad-

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6. National Science Foundation, NSF 56-15, "Research and Development by Nonprofit Research Institutes and Commercial Laboratories", U. S. Government Printing Office, Washington: 1956, 81 pp.

vanced academic degree is required for entry into employment at this type of an organization. In both types of organizations the research conducted has been overwhelmingly in favor of immediately applied research. The basic research type of work was reported at the non-profit institution for the fiscal year 1953 to be $3.3 million on basic research and the commercial laboratories reported an expenditure of $3.8 million on basic research. The above figures indicate that in the Non-profit Research Institute six per cent of their research expenditures was for basic research, their total budget for the fiscal year 1953 being just over $53 million.

The Commercial Laboratories with an expenditure of $24 million for research and development for the entire fiscal year gives a figure of approximately 11 per cent for basic research.

From the laboratories surveyed there appears to be no policy concerning the relative amount of basic <u>vis-a-vis</u> applied research that should be undertaken. Although the amount of research being accomplished by these two types of organization has increased substantially during the past ten years, the ratio of basic to applied research remains about the same.

Of the total research and development expenditures in 1953 for the non-profit and the commercial laboratories totaling approximately $77 million, it was re-

ported that about 62 per cent was derived from governmental contract.

Research Personnel

In both the Non-Profit Research Institute and the Commercial Laboratory the ratio between engineers and scientists engaged in research and development, and two supporting components made up of technicians, skilled craftsmen and other supporting personnel was approximately one for one. The Administrative Staffs consisted of over 27 per cent of the total personnel.

For the year 1954, it is estimated that the twelve research institutes employed approximately 3,000 engineers and scientists, and the total personnel in commercial laboratories doing research and development in 1953 employed approximately 1,180 scientists and engineers.

Shortage of Scientific Personnel

The much-talked-about shortage of scientific personnel did not appear to be serious in non-profit institutes. The commercial laboratories stated that they have experienced a shortage of research personnel in the past four years. There is a general feeling, however, that highly competent personnel are becoming more difficult to recruit and that the qualifications of the new personnel have decreased in recent years. Some place

the share of the responsibility for the lack of creativity upon the universities, which they claim have not met the greater need for scientists and perhaps more important, they have not emphasized a broad theoretical training.

Government and Research Programs

In both non-profit institutes and in commercial laboratories the Government is viewed as a necessary evil -- necessary because the majority of the contract work for such firms come from the Government and because government work in several fields assists most research organizations -- and evil because Government contracts carry with them great burdens (security, fiscal records, bookkeeping, auditing and progress reports). The common gripe is that we "earn less on a Government Contract than on a privately-sponsored contract of comparable size."

All knowing personnel in both non-profit institutes and commercial laboratories have suggestions for improvement in strengthening of our National Research Program; they range from Government contracting changes, auditing and accounting procedures, improved tax legislation, additional assistance to science education programs, and increased support of research, particularly for the mental research.

It should be noted, however, that although re-

search management claimed considerable irritation and frustration in the negotiation for research under Government contract, many technical persons have sympathy for the peculiar problems of Government. The Government must encourage research, but it must also protect itself against patent ownership. A general feeling is, "in order to strengthen our National research program, we must first have self-enlightenment, and enlightened self-interest."

History and Organization

The twelve non-profit institutes known to be conducting research and development are:[7]

Organization	Year Organized	Year Research and Development Began
Franklin Institute	1824	1946
Mellon Institute for Industrial Research	1913	1913
Battelle Memorial Institute	1925	1929
Herty Foundation Laboratory	1932	1932
Haskins Laboratories, Inc.	1935	1935
Armour Research Foundation	1936	1936
Southern Research Institute	1941	1944
Midwest Research Institute	1944	1944
Texas Research Foundation	1944	1944
Cornell Aeronautical Lab.	1946	1946
Stanford Research Institute	1946	1946
Southwest Research Institute	1947	1947

7. Ibid., p. 11.

In general these non-profit institutes do not undertake research projects for which they do not have a sponsor. Usually there is a very close relationship between the sponsor and the operating research personnel. Seldom does a research organization conceive an idea and then seek a sponsor. Usually middle-sized and large industrial companies seek out the research institute to do the work for them. This is also the case with Government-sponsored research and development, both applied and basic. One organization stated, "we all have some recognition of the need for more basic research, but this recognition becomes clouded when you put a dollar sign in front of it." Most non-profit research institutes have rather elaborate publications programs. The results of sponsored research are not published without the approval of the sponsor. Even house-research results, both basic and applied, are sometimes screened before publication by publications committees or some other designated agent within the organization. The general feeling among such organizations is that their publications stimulate interest in the institute and as an end result increase the number of sponsored research contracts. In effect they used the scientific publications as advertisements to attract sponsors or to encourage sponsors' ideas which might result in new contracts.

The Federal Government funds accounted for 66

per cent of the total and private industry funds accounted for 32 per cent. Thus, it appears that the Federal Government is supporting about two-thirds of the research and development work done by research institutes, and industry somewhat less than one-third.

Expenditure for Basic Research

Of the $3.3 million spent on basic research, chemistry and physics received 53 per cent of the funds and engineering sciences 26 per cent of the funds for basic research. Only nine of the twelve organizations conducted any basic research during 1953.

COMMERCIAL LABORATORIES

The history of Industrial Research Laboratories is that the overwhelming majority of them have been established since 1941.

The major volume of research of the commercial laboratories is applied in character and is performed at the request of the sponsors as is the case in most research laboratories. The sponsor, that is industry or government, presents the problem for solution to the Research Laboratory. These laboratories publish reports extensively. Their publications include articles in technical journals, advertisements in the journals, and publications or special brochures which describe the

research program of the organization. Most Government research contracts originate from Government requests for bids. There is practically no research of a non-purposive character in these laboratories. Almost all of the unsponsored projects are initiated in the hope of finding eventual sponsors. Most often unsponsored research originates with one of the firm's scientists and this individual has a personal interest and desire to follow such a project.

The majority of the industrially sponsored research of the Commercial laboratories comes from large firms. Only very limited work is done for small industrial companies.

There appears to be no policy concerning the relative amount of basic vis-a-vis applied research to be undertaken by the commercial laboratories. One firm has a policy of devoting one to two per cent of this time to "equity" projects (research projects that are unsponsored but from which the laboratory expects to derive income through some form of commercial exploitation).

The severest competition comes from industrial concerns which maintain their own research organizations to serve an industry, such as oil, chemistry, and electronics. In some cases the large industrial concerns will provide free customer service in their areas and these small commercial laboratories only receive the

overflow of work from the private laboratories of the big industrial concerns.

Research and Development Expenditures, Commercial Laboratories, 1953

A significant factor to be observed in this type of laboratory is that two per cent of the laboratories conducted over 40 per cent of the total research and development expenditures. An additional four per cent conducted over 22 per cent of the research and development and the next six per cent of the firm in the group conducted 15 per cent of the total research and development expenditures. In other words twelve per cent of the firms in the group conducted 77 per cent of the total research and development expenditures by firms in the group.

On the average, for all commercial laboratories, over half of all research and development expenditures had their origin in Government contract work.[8] Over 50 per cent of the commercial laboratories feel that the Government is performing research in their field of endeavor that would not have been done by non-government agencies.

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8. *Ibid.*, p. 29.

RESEARCH AND DEVELOPMENT IN PRIVATE INDUSTRY

Nearly 20,000 companies contributed to the country's research and development effort during 1953. Over three-fourths of these organizations conducted research and development in their own facilities. The majority of the companies conducting research and development were small manufacturing firms. Of the approximately 15,000 companies doing research and development work, nearly 14,000 were in the manufacturing industry, and nearly 12,000 (85%) of these manufacturers had between eight and 499 employees. Only about 300 companies had as many as 5,000 employees.[9]

Out of the United States total of more than $5 billion of research and development work conducted during 1953, approximately two-thirds of this work in the natural sciences and engineering was conducted in private industrial laboratories. Part of this work was funded by governmental agencies, educational institutes and other non-profit institutions, as well as the funds from private industry.

The basic research conducted by private industry represented approximately $150 million, or approximately four per cent of the total expenditures for research and development in industrial laboratories.

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9. NSF 56-16, <u>Op. cit.</u>, p. 3.

From fiscal year 1953 to fiscal year 1954, the expenditure for research and development programs in industrial laboratories rose about twelve per cent. The 1953 figure was $3.7 billion and the 1954 figure was slightly over $4 billion.

Over one-third of the research and development work performed by private companies was conducted for the Federal Government on either research and development or procurement contracts at a cost of about $1.4 billion, leaving the remainder of approximately $2.3 billion for research and development programs financed by the companies conducting the work. It is estimated that the companies spent over $100 million for research and development performed by colleges and universities, commercial laboratories, and other outside organizations.

Scientists and engineers employed in research and development activities in industry represented approximately 157,000 in January, 1954. The supporting personnel (which included technicians, administrative, and other supporting personnel) as well as scientists and engineers, gives total of persons employed in industrial research and development as well over 400,000 employees. Over-all this gives a ratio of one to three scientists and engineers, or approximately 30 per cent of all engineers and scientists employed by private industry of all types of activities are employed for research and development. It is estimated that the entire

number of scientists and engineers employed in private industry is 550,000.[10]

COST OF RESEARCH AND DEVELOPMENT IN PRIVATE INDUSTRY

The cost of conducting research and development in the aircraft and electrical equipment industries far exceeds all others in scale of their research programs. The expenditure of these two industries together was about $1.5 billion in 1953, or approximately two-fifths of the grand total for all industry expenses. The survey conducted by the National Science Foundation indicated that next in the size of their research and development programs were the motor vehicle, chemical, machinery, professional and scientific instruments, petroleum, telecommunications and fabricated material products industries. About 90 per cent of the total expenditures on research and development by industrial research organizations was accounted for by these nine industries.

The aircraft and electrical equipment manufacturing industries are also the industries with the largest Government-financed research and development programs. The aircraft industry received approximately $640 million and the electrical equipment company received about $400 million. Together this amounts to

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10. Loc. cit.

more than three-fourths of the total cost of research and development work done in private industry under Federal Government contracts.

An unusual situation concerning the concentration of research and development in large companies has been disclosed by this survey. The research and development activities are concentrated in large companies to a greater extent than production of industrial activities as measured by employment. Companies with 5,000 or more employees accounted for over 70 per cent of the research and development work, whereas their share of manufacturing employment was not quite 40 per cent. In contrast, firms with less than 500 employees accounted for only ten per cent of the research and development cost though they employed 35 per cent of all workers in manufacturing.[11]

Supporting Personnel in Research and Development

The average ratio of supporting workers to research and development scientists and engineers varied from 1.8 to one in companies with less than a thousand employees to an average of 2.7 to one in the large research installations. Supporting personnel include draftsmen, technicians, skilled draftsmen, administrative, clerical, maintenance and other supporting workers.

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11. Ibid., p. 4.

Support ratios varied widely among companies within the same industry. However, in general it could be said that aircraft manufacturers have the highest support ratios whereas chemical, foods, metals, and professional and scientific instruments have the lowest number -- only about 1.1 to one.

AVERAGE COST RATIOS

The average cost of private industrial research and development expenditures per scientist and engineer employed varied between $15,000 in the rubber and food industries to $30,000 in the industry motor vehicle segments; to $27,000 in companies employing 1,000 or more employees; to a high of $36,000 per scientist and engineer in the "Manufacturing Industries".

A significant ratio of all companies involved was the average ratio of research and development cost to value of sale and this in general was 1.7 per cent for the large and medium-sized companies (1,000 or more employees). Again the aircraft industries had the highest ratio and this was 8.9 per cent; electrical equipment and professional and scientific instruments industries were the next highest with 5.9 per cent and 4.8 per cent, respectively. In the Aircraft Electrical

Equipment and Professional and Scientific Instrument Industries the Government contracts accounted for relatively more of the research and development cost than in any other industry for which figures were available. This shows that the amount of Government-financed research greatly influences the ratio between sales and dollar volume of research and development activities in these industries.

EXPENDITURES FOR RESEARCH AND DEVELOPMENT BY INDUSTRY AND GOVERNMENT

The cost of Government-financed research and development related to total cost of research and development in industry are as follows: for all industries combined, the cost of Government-financed research and development as a per cent of the total was 37 per cent; for the aircraft and parts industries, cost of Government-financed research and development was 84.4 per cent; for electrical equipment, 54.5 per cent; professional and scientific instruments, 44.7 per cent; telecommunications and broadcasting, 52.2 per cent; machinery, 17.9 per cent; fabricated metal products and ordnance, 31.6 per cent; chemicals and allied products, 2.5 per cent; petroleum products and extracts, 5.6 per cent; primary metal industries, 7.6 per cent; and other industries, 7.4 per cent.

Basic Research

Basic or fundamental research is defined as research projects which are not identified with a specific product or process application, but rather have the primary objective of adding to the over-all scientific knowledge of the firm. This definition was derived from one developed in a study conducted by the Harvard Graduate School of Business Administration incorporated with the U. S. Department of Defense, National Association of Manufacturers, and Industrial Research Institutes.

For private industry as a whole, the cost of basic research performed in 1953 is estimated at approximately $150 million. This figure represents only four per cent of the estimated total research and development cost of $3.7 billion.

The chemical industry far exceeded all others in the magnitude of its basic research program. Estimated expenditures were $38 million; therefore, the basic research cost for the chemical industry represents 25 per cent of the total for all industries. The electrical equipment and aircraft industries ranked second and third in extent of basic research. The cost of the electrical industry was estimated to be $19 million and the expenditures for basic research in the aircraft industry were estimated to be $18 million.

It was stated by nearly all companies inter-

viewed that the natural relationship between the field in which the companies conduct the basic research and the companies' primary business interest was significant, and was attested to in the interviews with research officials.

EMPLOYMENT OF SCIENTISTS AND ENGINEERS

The total number of engineers employed in private industry, not only in research and development activities but also in production, administration, and many other types of scientific and technical work, represents a great force of scientists and engineers. Altogether, more than 550,000 engineers and natural scientists are employed by private industry.

The first and most obvious group are engineers and scientists in different professional fields. It is estimated that there are 409,000 engineers employed and they represent the largest occupational group. The employment of the next largest group, chemists, was estimated at 60,000, or only 15 per cent of the employment figure for engineers. Metallurgists, earth scientists, physicists, and mathematicians together numbered only about 35,000. In addition there were some agricultural, medical, and biological scientists numbering about 10,000.

There were approximately 34,000 scientists and

engineers who were classified by their companies as administrators, rather than members of a particular scientific or technical profession. This definition of administrator should not be interpreted as meaning all scientists and engineers engaged in supervisory or administrative work, but rather as comprising those regarded by their companies as primarily administrators, rather than engineers, chemists, physicists, or scientists of other specified types. When combining the total number of scientists and engineers employed in Government agencies, colleges and universities, and other fields outside this scope of American industry, it appears that the industries covered by this survey employed about half of all scientists and two-thirds of all engineers that were in the continental United States.

EMPLOYMENT IN RESEARCH AND DEVELOPMENT

It has been estimated that approximately 157,000 scientists and engineers, nearly three out of every ten in the United States, are currently working in research and development either full time or part time.

Engineers are employed in a wide range of industries, but most work in metal working and other industries with highly complex knowledge. Industries included in the metal working category are: primary metal

products, fabricated metal products, ordnance, machinery, electrical equipment, aircraft and parts, motor vehicles, other transportation equipment, and professional and scientific instruments. Over one-third of these engineers and scientists were in three of these industries: machinery, electrical equipment and aircraft.

The aircraft industry output is for use by the military primarily, and constant modification of aircraft models is necessary to meet the requirements of advancing military technology. Development work looms larger in the total production process and aircraft manufacturing than in other major industries. Major expenditures in private industry are declining for aircraft and increasing for guided missiles and in the year 1961 the two curves will cross or in other words, at that time the total expenditure for aircraft including research and development and production, will be equal to the total expenditure for guided missiles, both research and development and production. Private Industry has been paying a larger percentage of the bill for research and development of aircraft than they have been or will be paying for research and development of guided missiles, because there is a civilian application of the aircraft, and when it was developed specifications were presented to the Government or military departments on a take it or leave it basis as it was de-

signed. The significant difference between this and future research and development, specifically on guided missiles and intercontinental ballistic missiles, etc., is that the weapon itself, in the case of a missile, is considered the primary and most important objective and the wings and controls to make it fly and guide are secondary and are added only as a means of delivering the primary weapon to its target. Therefore, the conclusion is that as we progress on into the future the role of Government research and development will become greater and the percentage of dollars paid in this industry will become greater and greater -- a government-support industry.

COMPANIES OWNING PATENTS

Most companies conducting research and development programs own patents and have patents pending. The survey conducted by the National Science Foundation[12] stated that 55.3 per cent of the companies both owned patents and had applications pending; 15.1 per cent owned patents but did not have applications pending; 4.9 per cent had no patents owned but applications were pending; and 24.7 per cent stated that they neither owned patents nor had any applications pending. The

12. *Ibid.*, p. 37.

statistics further point out however, that the importance of patents to a great number of small business organizations, as well as leading corporations and industries, have significant research and development programs. Since the patents owned by a company are, in general, the fruit of a long-continued research program, the cost data reviewed earlier indicates that it is somewhat more economical for small companies to obtain patents than larger research laboratories.

Competition apparently provides the underlying stimulus for company-financed research and development, and it is interesting to note that research and development activities in private industry depend upon the amount of government-financed research and development conducted at their establishment. Many companies have reported that if a substantial reduction in Government contracts were to take place, this would result in immediate reduction of research and development activities, at least temporarily, because companies with large government research and development programs could not increase their own programs sufficiently to offset sharp reductions in Government-sponsored work. On the other hand, most companies report that substantial increases in Government research and development contracts would probably <u>not</u> lead to an equal expansion in industrial research and development as a whole, owing to the shortages of well-qualified personnel. The basic re-

search which is conducted in private industry stems primarily from problems encountered in applied research areas, and basic research is more easily funded when the value of certain basic information in a specified field of interest for a specific company can be clearly defined.

EVALUATION OF RETURN ON RESEARCH

The vast majority of companies have not found a fully satisfactory solution to the evaluation of research and development. Most companies express great interest in valid methods of measuring returns on research as a basis for improved research planning and budgeting. Only about one-fourth of the companies interviewed have developed formal methods for such evaluation. Some of the methods upon which evaluation is determined are first judgment appraisals of the contributions of research on such items as the proportion of the total company's business, the percentage of total products on the market, the number of patents granted which can be traced to the company's research effort, and so forth. Others are based upon judgments, such as success of new products or the general progress of the company.

Captain Edwin Hooper, Assistant Chief of the Bureau of Ordnance for Research and Development stated

at a Sloan seminar that in his opinion there are three ways of arriving at an initial evaluation of how a laboratory is doing: first, are they meeting their time schedules as planned; second, are they producing new items with significant improvements over old or conventional items; and third, are they operating within their budget limits or are they living within their original cost estimates for conducting a certain job? Captain Hooper pointed out that research and development is an ever-changing field and that the dollar signs or dollar values assigned to a project would be at least third in priority in arriving at an evaluation system for research activities.

In general, companies engaged in basic research do <u>not</u> budget separately for basic and applied research programs. Some companies, however, attempt to assure a continuous program of basic research by specifically allocating funds for that type of work at a relatively constant proportion of the over-all research and development budget.

<u>FEDERAL FUNDS FOR SCIENCE</u> (The Federal Research and Development Budget Fiscal Years 1955, 1956, and 1957.)

Since 1953, the National Science Foundation has been publishing data on the Federal Research and

Development budget in a series of reports entitled "Federal Funds for Science".[13]

The data for fiscal 1955 are based on agency records for the entire year. The fiscal 1956 data were obtained from estimates approximately half-way through the fiscal year and the fiscal 1957 data are those requested in the President's budget. The estimates therefore, do not reflect Congressional action and should be used as guides only until later figures come out which are definite. The total Federal Government expenditures for scientific research and development were estimated approximately as follows: 1955, $2.3 billion; 1956, $2.4 billion; and 1957, $2.7 billion. These figures show an advance of almost seven per cent in Fiscal Year 1956 over the previous year and an anticipated increase of twelve per cent in Fiscal 1957. From the limited knowledge and background of this author, it is customary to predict increased budgets. In addition to these research and development funds, engineering type work similar to many development projects that are funded from research and development appropriations should be added. They are as follows: $6 million for 1955; $7 million for 1956; and

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13. National Science Foundation (NSF 56-19), "Federal Funds for Science", (The Federal Research and Development Budget Fiscal Years 1955, 1956, and 1957), U. S. Government Printing Office, Washington; 1956, 47 pp.

$7 million for 1957.

It has been estimated that 85 to 95 per cent of the total research and development funds will be expended on research and development and that the remaining funds will be spent for research and development facilities in plants.

There are between 24 and 25 separate agencies in the Federal Government spending funds for scientific research and development, that is, if you consider the Department of Defense as a single agency. However, the significant expenditure of research and development funds, 99 per cent of the total, is obligated by eight agencies: Department of Defense; Atomic Energy Commission; Department of Health, Education, and Welfare; Department of Agriculture; National Advisory Committee for Aeronautics; Department of Interior; Department of Commerce; and National Science Foundation. These same agencies account for 99 per cent of all obligations and expenditures for the conduct of research and development.

The Department of Defense, Atomic Energy Commission, and National Advisory Committee for Aeronautics administer 95 per cent of the total funds for the physical sciences. The Department of Defense estimated budget for fiscal year 1956 was $1,904 million and for fiscal year 1957, $1,936 million. The Atomic Energy Commission fiscal year 1956 estimate was $489

million and the fiscal year 1957 estimate was $529 million. The National Advisory Committee for Aeronautics fiscal year 1956 budget was $73 million and the fiscal year 1957 estimate was $80 million. The total obligations for research and development in the physical sciences are estimated to be $1,944 million in the fiscal year 1956 and $2,075 million in fiscal year 1957.

APPLIED RESEARCH-BASIC RESEARCH

Approximately 90 per cent of the Federal Budget is spent on applied research and it is estimated that only nine per cent of the total Federal Budget is spent on basic research. However, basic research is growing in terms of Federal funds provided for this purpose, and they are estimated to be twice the percentage of basic research funds in private industries.

There are only two Federal organizations which support basic research exclusively. They are the Smithsonian Institution and the National Science Foundation. It is estimated that the total basic research dollar expenditures for physical sciences in 1955 were $85.7 million, in fiscal year 1956 $108.7 million, and in fiscal year 1957 $138.8 million, whereas the expenditures for applied research and development in the Physical Sciences are estimated to be in fiscal year 1955 $1,570.1 million, in fiscal year 1956 $1,835.6

million and in fiscal year 1957 $1,935.8 million.

DISTRIBUTION OF FEDERAL FUNDS

The Government spends 47 per cent of its total research and development dollars within Federal Government establishments, 38 per cent is spent at profit organizations, 13 per cent is spent at educational institutions, and two per cent is other organizations. Included in the expenditures to profit organizations, educational institutions and non-profit groups are obligations for research centers which are Government-financed research installations managed for the Government by each of these types of organizations. The Department of Defense obligated over 77 per cent of the total funds going to profit organizations. The Atomic Energy Commission accounted for an additional 21 per cent of Federal funds going to profit organizations, giving us a total of 98 per cent of the expenditures between the Department of Defense and the Atomic Energy Commission to profit organizations.

The Department of Defense and the Atomic Energy Commission provided 77 per cent of the total obligations for educational institutions and affiliated research centers in fiscal year 1956.

FEDERAL RESEARCH AND DEVELOPMENT TRENDS

It must be pointed out that the overlapping or gray area between research, development, test and procurement is not a clear distinct area. The gray areas, or so-called overlapping areas, vary from one project to another or from one phase to another. Also within the Department of Defense there exists a significant difference between the Air Force, Army and Navy as to the funding for test and procurement of testing models. The Department of Defense reported estimated expenditures for the engineering-type portion of production and procurement funds that directly support research and development, excluding quantity production of prototypes for weapons and equipment, as follows: fiscal year 1955, $635,000,000; fiscal year 1956, $630,000,000; and fiscal year 1957, $665,000,000. It is estimated from currently available unclassified data that the funds for research and development plus funds for activities directly supporting the research, development, test, and evaluation programs, total approximately $5.2 billion for fiscal year 1957.

The total support for research and development work for fiscal year 1957 is estimated to be $5,194.6 million. This breaks down approximately as follows: new obligational authority for research and development appropriations, $1,648 million; activities supporting

research and development, $607 million, which breaks down to $323.9 million for military construction, $87.2 million for industrial facilities and $196 million for military personnel engaged in research and development supporting work; development, test, and evaluation items $2,939.2 million, which break down to aircraft having $521.9 million, guided missiles having $1,865.7 million, shipbuilding $153.6 million, and all other $398.0 million.

The obligation of Federal funds within the Department of Defense for the conduct of research and development for fiscal years 1955, 1956, and 1957 are indicated in the breakdown as follows: total Department of Defense basic research in fiscal year 1955, $20,421,000 of which the Air Force spent $9,009, the Navy spent $7,748, and the Army spent $3,583. The applied research and development for fiscal year 1955 total for the Department of Defense was $1,508,268,000 of which the Department of the Air Force spent $677,541, the Department of the Navy $419,786, and the Department of the Army $389,281. In the fiscal year 1956 the total Department of Defense expenditure for Basic Research is $27,185,000 of which the U. S. Air Force spent $15,137, the Department of the Navy $7,899, and the Department of the Army $4,149. The total expenditures in fiscal year 1956 for applied research and development for the Department of Defense was $1,696,413 of which the Depart-

ment of the Air Force spent $123,091, the Department of the Navy $505,373, and the Department of the Army $430,749. The total basic research for the fiscal year 1957 for the Department of Defense is estimated to be $27,789,000 of which the Department of the Air Force will spend $15,615, Department of the Navy $8,025, and the Department of the Army $4,149. The total Applied Research and Development for the Department of Defense for the fiscal year 1957 will be $1,728,174 of which the Air Force will spend $695,737, the Navy $496,081, and the Army $536,356.

A major aspect of American culture and technology in recent decades has been the growth of research and development in the natural sciences. As human and other resources devoted to research have increased in volume, a need has arisen for data on the total volume of this activity and the nature and magnitude of its components. For a summary of the expenditures for research and development conducted by organizations in the various sectors of the economy, using the year 1953 as a starting point, see Appendix 2.

CHAPTER V

UNRELATED ADMINISTRATIVE AND MANAGEMENT AREAS TO BE CAREFULLY STUDIED

Technical Direction of Research Activities; Military Personnel Policies; Military Support Activities at Research and Development Installations; A Top Management Team of Administrators; Fiscal Procedure; Scientific and Technical Personnel, Conditions Under Which Personnel Work; Security; Civil Service Restrictions and Regulations: Flexibility ("in House versus Contracted"); Decentralization; Communications; Industry Executives' Viewpoint on Government Research Relationship; Review of Industrial Research, Coordination, Control and Financing; Research and Development Contracts Awarded 1954-1956 Inclusive; Training; Comparison of United States and Soviet Scientific and Technological Progress; Patterns of Organization for Applied Research and Development; How Good Are Corporate Scientists?

There appear to be many distinct unrelated areas which require careful review and consideration in the control and administration of the Government research and development program under the Military departments.

TECHNICAL DIRECTION OF RESEARCH ACTIVITIES

Clear distinct authority and responsibility must be delegated to the civilian technical deputies or assistants with sufficient authority over the technical

aspects of the program in order that these civilian technical deputies can control the technical policies, program progress, etc. Both military and civilians responsible for technical direction of our programs must be fully competent both in the sciences and in management to manage and integrate the entire program. Technical direction of the research and development programs must have continuity. The recruiting, reassignments and appointments of scientists and technical personnel must follow a logical and reasonable pattern. The weapons systems coordinator, project leader or research team leader must be capable and competent to do the job and thereby instill in his subordinates competence, a degree of enthusiasm toward his work, and respect for the policy decisions from those above throughout the entire organization. During the Riehlman hearings, several former chief scientists and technical deputies indicated that they resigned from their positions because the military commanders had a dis-inclination to vest authority in their civilian technical deputies or assistants. This emphasizes the necessity for careful review and consideration for both the civilian technical assistants and for the military personnel who are to be working in the programs. This includes both military commanders and staff or other policy-making officers.

An example of an excellent arrangement of technical direction from civilian scientists and admin-

istrators to military administrators is reported in the Riehlman hearings,[1] "Operating Principles" issued to the Naval Ordnance Laboratory by the Bureau of Ordnance approved 28 December, 1951 by RADM M. F. Schoeffel, Chief, Bureau of Ordnance. Dr. Ralph Bennett, the former technical director of the Naval Ordnance Laboratory, White Oaks, Maryland, has stated that when the work of an installation is largely of a technical nature, delegated authority to the senior civilian technical director must be adequate for the control and direction by this senior civilian. He has further stated that for the long-run health, growth, and morale of the research organization the stated objective or mission for the station should be promulgated from higher authority. This organization charter or laboratory mission should clearly state the respective roles of the commanding officer and the technical director (civilian) and in general should insure the stability of general operating policies. During the Riehlman hearings, Mr. Sol Skolnik (N.P.F.), a civilian scientist in a military research and development program, stated,

> "The scientist is trained to be objectively critical of his own efforts and the efforts of

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1. Riehlman Hearings, Op. cit., p. 117 ff., 323 ff., 476 ff.

> his colleagues. This attitude is different from that of the military officer whose training and experience has been to accept orders from superiors without question. There is ample justification for each type of training in the respective fields. Therefore, the scientists should be charged with the responsibility for research and development and supplied with the necessary authority to efficiently discharge his responsibilities; the military should be charged with the responsibility of delineating the problem, with the supplying of all pertinent information and with the authority to accept or reject, as the user, the results of research and development effort."[2]

As stated earlier, there is a new breed of military officer who is being educated at universities, industrial laboratories, etc., in the arts, sciences, industrial management, etc. With the proper review and selection of military and civilian personnel, the differences in background training and responses to research and development or policy decisions would become negligible.

MILITARY PERSONNEL POLICIES

The rotation policy of the military officer has been established for many years. Excellent results from the military point of view have been achieved in obtaining well-trained military personnel with broad operational backgrounds.

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2. Ibid., p. 690.

It can be generally stated that officer personnel are rotated among diversified assignments with tours approximately two to three years for normal assignments and in some cases, four years for technical and scientific assignments. These officers are promoted to higher rank on the basis of military evaluations other than research and development accomplishments. The Riehlman Sub-Committee states:

> It appears clear to the sub-committee that military personnel career requirements are basically different from those of scientists and other technical personnel, and that rotation is understandably necessary in order that military officers might familiarize themselves with a variety of military operations. The sub-committee recognizes the unique need for military rotation, but accelerated rotation programs which result in short tours of duty, are both disturbing and harmful to the productivity of the research and development program.
>
> At the commanding officer level short tours of duty might not in themselves be harmful if the officer is primarily fulfilling a military need for his having a variety of experiences. Difficulties do appear, when an officer fresh from the field and with limited technical experience enters a research center with a view to reorganization based on limited technical qualifications.
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> Most scientists acknowledged that they respect a qualified line officer with an intelligent consumer point of view. Scientists realize, however, that all too often qualified officers are transferred to another assignment within a short period of time.[3]

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3. Sub-Committee Report, "Committee on Government Operations, Organization and Administration of the Military Research and Development Programs, (August 4, 1954), Union Calendar No. 895, House Report No. 2618, p. 34 and 35.

The above quotation from the Riehlman Sub-Committee on Organization and Administration describes a situation not so different from that of many of our large industrial concerns -- for example, the policy of rotating junior officials of middle management and senior management within a given company. It is the policy of several large companies surveyed to rotate their middle management personnel frequently. This is used as a training method as well as an educational method for the individual. Excellent communication can be obtained between activities of the same company or organization by the transfer of selected individuals from one part of the organization to the next part of the organization. It is true that the top managers or policy-decision personnel should not be included in this frequent transfer except in the cases of an emergency or in setting up a new organization. Therefore, the rotation of personnel within organizations is not unique to the military.

As a result of the experiences gained by the author of this paper during this year of graduate study, it would be my recommendation that more rotation of top technical and scientific personnel take place on a planned and scheduled basis throughout each of the agencies in the Department of Defense. For example, young college graduates recruited into the field stations and laboratories after two or more years of working

on scientific projects could be given an opportunity to become a project leader in the technical areas at the respective field stations, or to enter the planning, coordination and control of research activities of the field station. Also they would have an opportunity to transfer to the next higher office and eventually to planning, programming and coordinating at the home office or Washington, D. C.

An integrated, planned program of this type would present opportunities for promotion to the scientists and technological-minded individuals who desire the atmosphere of the laboratory working on specific projects, and opportunities would be presented to those desiring to expand into administration and management. Finally the home office or policy-making organization would have available on a planned program the best qualified individual familiar with the program, oriented in the arts and sciences peculiar to this organization, and could present to these individuals opportunities for promotion in the management and administrative areas of their sciences and technology. The advantages of intercommunication, familiarization and orientation of both the technical field stations and research laboratories, and the communications with the home office to the field would be greatly improved. At the present time this type of rotation has been limited primarily to military personnel. In the opinion of this author, the

above rotation and exchange program should be instituted in the civilian program in much the same manner as it currently exists for military personnel. The above-described training program would provide a pool of qualified civilians familiar with military policies and functioning within government organization, from which adequately trained administrators and management personnel or scientists could be drawn for advancement to the higher offices within the organization. This program would not interfere with the existing rotation plan of the military, providing clear distinct lines of responsibility and areas of performance were described to both the military and the civilians. It is the opinion of this author, that if a training and orientation program of the above type were to be initiated for both military and civilians in the area of research and development, the result would be a greater appreciation for the difficulties and limitations of normal communications and also a better exchange of information and ideas between civilian technical personnel and the civilian scientists at the laboratories, as well as between all levels of the military and civilians within the entire organization. By such a policy the civilians in the program would have closer ties, confidence, loyalty, and a feeling of belonging to their respective military organizations. This long-range plan of training and orientation would result in a feeling of career develop-

ment in research and development within the Department of Defense. The program should include technical people, policy-making people, and administrators and management types, both within the military and within the civilian organization. As stated earlier, it is the opinion of this writer that the management and administrative opinions of both the civilian and military will be very similar. The scientific opinions and policy opinions will vary considerably whether they be made by civilian or military personnel.

MILITARY SUPPORT ACTIVITIES AT RESEARCH AND DEVELOPMENT INSTALLATIONS

During our rapid expansion of research and development in the World War II era and during the ten years immediately following, various types of military supported activities and the management and functioning of military organizations and administration at various types of scientific and research laboratories have been experimented with, and much data is available now as to what is good and what is bad.

It must be pointed out that each military installation varies as to its composition of civilian scientists, the support functions required, the primary objective of this installation, etc. Much emphasis and much consideration must be given specifically to the top

military staff and to the top civilian scientists or administrators in working out the areas of agreement, areas of gray consideration, and areas of disagreement.

Frequently there is a tendency on the part of the civilians at a station to feel that the support function of the military is something that must be provided to them when they want it, how they want it, without any consideration for cost, training, and the organizational objective of the supporting unit. It has been reported that at some installations the support function of the military has been so emphasized that it detracted from, and tended to eliminate from its objective, the research and development aspects of their work. This area is not one that can be viewed from afar and have general statements made as to what would be good and what would be bad. In general, the objective of each agency within the Department of Defense should be to establish a more efficient type of research laboratory, test area or functioning group to perform the necessary functions.

A TOP MANAGEMENT TEAM OF ADMINISTRATORS

Military and civilian teams that work together with the primary objective of getting the job done will be able to deal with the minor problems between the technically-minded scientists and the support units furnish-

ing equipment, personnel, transportation, supplies, housekeeping, housing for personnel and equipment, test instruments, laboratories, etc. An excellent example of the superior personnel relationship between the scientific group and the supporting group exists at the Naval Ordnance Test Station, Inyokern, California. Informal relations exist between all levels of all organizations at the Naval Ordnance Test Station. Within the general framework of support functions and research and development, top level committees composed of both military and civilian experts are formed to give policy guidance to the specific weapons systems. Both scientific and administrative as well as support and policy matters are considered by these policy committees and by the conference method. An agreed-upon coordinated program receives the support of all layers of management in all phases of the research and development program.

A major problem within the Department of Defense, Research and Development Laboratories, is the supplying of facilities and equipment necessary to accompany the rapidly expanding research and development projects. This critical limitation is not limited to only the government-operated and managed research and development laboratories, but extends also to the contractor-operated, the university-operated, and the laboratories in private industries with whom the govern-

ment has contracts.

The funds used for research and development are appropriated by fiscal year, supposedly with considerable flexibility in the use of these funds for various portions of the research and development program. The numerous levels of reviewing officials between the operating bureaus of an agency and the Department of Defense, as well as reviewing levels within each of the agencies, the Army, Navy and Air Force, are continually imposing additional restrictions on the use of these funds. Even after the Department of Defense, the Bureau of the Budget, the President, and the Congress have approved a research and development expenditure program for a given fiscal year, these funds are not made available to the operating bureaus or research and development laboratories as a lump sum for an annual planned and programmed operation. Certain committees impose their restrictions on funds waiting for other advancements to be made or waiting to see how one weapon ties to another or how one agency's field station is being evaluated against another's agency field station, or contractor, or university, or private industry contract. In all cases this makes a yearly planned program difficult to manage.

The Department of Defense Advisory Committee on Fiscal Organization and Procedures, Research Activities Working Group Report on Research and Development

stated:

> To have research and development installations prepare budget estimates in complete detail so far in advance (18 months) serves to waste a great amount of effort and encourages the padding of estimates as a protective measure. Research and development is, by its very nature, a constantly changing and substantially unpredictable effort and, consequently, not readily adaptable to detail budgeting so far in advance.[4]

In the experience of this writer the above statement is understated. Not only do the operating installations, Bureaus, Departments and Agencies prepare detailed fiscal estimates 18 months in advance, they also prepare fiscal estimates two, three, four, five and more years in advance. In fact, many organizations presently are preparing fiscal estimates ten years in advance. It is the opinion of this writer that these are excellent for planning purposes, but the minimum of time and effort should be exerted defending the details.

FISCAL PROCEDURE

It is difficult to fund a research project that cannot be described either as to characteristics,

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4. U. S. Department of Defense, Office of the Secretary of Defense, Advisory Committee on Fiscal Organization and Procedures. Research Activities Working Group, Report on Research and Development, Washington, July, 1954, p. 39.

performance, time schedule, etc.

Three difficult and important areas have been recognized by the Advisory Committee on Fiscal Organizations and Procedures. They are:

1. Budgets should be revised as few times as possible. Complete submissions should be required from the installation level only twice, and initial estimates and a revised estimate when the amount of funds to be made available becomes known or can be anticipated. In the interim, budget revisions should be limited to special, large-scale items of measurable consequence.[5]

2. Each service should allocate and allot to each installation, its research and development funds as follows: (1) For internal operations, a single allotment administratively limited to one year; (2) For capital equipment, a separate allotment with no time limitations; and (3) For contracting, a separate allotment with no time limitations.[6]

3. In executing the research and development under each allotment, deviations should be permitted within each allotment total; manpower ceiling, however, must be observed.[7]

Since the operating manpower-ceiling must be observed as a separate restriction from the dollars available for research and development, this presents a considerable problem for contractor-operated research

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5. Ibid., p. 41.
6. Ibid., p. 48.
7. Ibid., p. 51.

and development laboratories, contracts with private industry, and with universities. It conceivably could be possible and feasible that research and development dollars would be available to spend on a weapons system or on a research project of considerable magnitude, yet the manpower ceilings, both military and civilian, would not allow the expansion of the facilities of government-owned laboratories or government-managed laboratories to accommodate the work. In this case there would be no restriction as to the number of scientists, engineers, administrators or management personnel that could be contracted to perform this service or duty.

CONDITIONS UNDER WHICH SCIENTIFIC AND TECHNICAL PERSONNEL WORK

Many of our government-owned military research and development laboratories are the best equipped, most modern and advanced laboratories in the world today. The military research and development program supports investigations into the latest sciences, electronics, atomic phenomena, and supports the application of the basic research learned in these scientific fields to engineering and design of specific weapons systems, hardware items, or usable pieces of equipment. Therefore, the scientist or engineer desiring to work in the scientific fields dealing in new areas where unknown

phenomena and expanding technical knowledge are growing rapidly, can work in an atmosphere in a government laboratory which has an unlimited horizon. A young scientist or engineer entering into weapons system work, planning and coordinating of research in scientific activities of the government, obtains an education within the arts and sciences as well as contacts with responsibilities for all parts of the government program. In general, these younger research scientists, engineers, administrators, and managers are held accountable for more responsibility over a broader area in a government laboratory than are their counterparts in the civilian laboratory. They obtain experience in planning, coordinating and controlling projects as well as in the administrative and contractual aspects of these weapons systems or scientific areas. A large number of civilian scientists and experts from private industries and universities accept consulting jobs with the military departments and visit the laboratories frequently to make recommendations on the scientific work, the management, the planning, etc. The military departments sponsor and promote scientific meetings which are attended by experts from all phases of the Department of Defense, private industry and universities. Except for highly classified information, the group is cleared in advance and the latest scientific and technical information is made available to all present. The

current government regulations allow engineers and scientists working for the Defense Department to travel to scientific and professional society meetings. Employees are encouraged to prepare for publication technical papers which must be written in view of the currently existing security of the item being discussed. Also, the Department of Defense employees are permitted and encouraged to present papers, talks or discussions at professional society meetings, providing the talks and discussions do not reveal aspects which are covered by classification restrictions. During the Riehlman hearings, one prominent scientist stated:

> There is no reason why a civilian employee in the Defense arm should be less in stature for his position than a uniformed employee, nor why delegation of authority from the Department head to such an individual cannot be made. The disproportionate technical training required to achieve a certain position of research direction in civil and military lines, results in a marked discrepancy. The Department of Defense actually uses additional civil-service classification procedures, over those used by non-military agencies of the Government, and which appear to impede classification and discourage civil employment in defense technical laboratories.[8]

Military Operation experience is a vital growing factor in research and development of new weapons and equipment to be designed to meet military needs.

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8. Riehlman Hearings, Op. cit., p. 643.

Therefore, the keen approach previously described must be continued in order to obtain the most efficient weapons which are needed by our operating forces, in the shortest period of time, and for the least amount of money. Additional incentives must be provided for scientific and technical personnel, as well as for military personnel. During the Riehlman Committee Hearings, the objective of a combined scientific and technical program, composed of both military and civilian personnel, was summed up by L. A. DuBridge as follows:[9]

1. The research program must be interesting and challenging.

2. The need for the solution must be apparent and real.

3. The leadership must be superb.

4. The working conditions must be positively attractive.

5. Great freedon must be provided for individual initiative and for the investigation of individual and original ideas.

6. The organizational structure must be effective, but "red tape" must be reduced to a minimum.

7. There must be positive opportunities and incentives for interchange of ideas -- between members of the same group, between different groups, and between different laboratories or organizations having similar interests.

8. The military needs must be expressed in

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9. _Ibid._, p. 654.

terms of combat problems, not solely in terms of technical specifications.

9. The attitude of the military must be not that they are ordering a device from the factory, but that they are inviting the scientists to help solve a tactical or strategic problem.

The above factors could achieve a well-balanced, superbly supervised, and managed research and development program which would be an excellent goal for any laboratory in a university, private industry or government. The primary consideration must be given to the conduct of the research and development work with the least amount of interference from normal housekeeping or support activities and with the least amount of interference from normal regulations from any outside body.

SECURITY

The security requirements within a government laboratory place the responsibility on each individual not to discuss recent information and it places upon each individual the responsibility for securing his desk or his file, his laboratory or his working area. These restrictions generally require that all classified material be placed under a three tumble lock in a file cabinet approved by a security guard or inspection official, and two or more violations of this type subjects

one to the possibility of reprisal, such as loss of pay for a period of time, or in the case of any serious offense, a complete loss of one's job.

Dr. James Killian, President of Massachusetts Institute of Technology, has stated:

> "I believe that the whole problem of security procedures and policies at the present time may be one of the things that is most hazardous to our future research and development activities in this country in relation to military problems.
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> "The feeling that the present security procedures can be handled and administered in a manner to damage creative activity and if they are, the feeling that the giving of an unbiased and objective judgment can be, under certain conditions, dangerous to the giver because this unbiased judgment does not accord with somebody's policy, all of these things add up to a great discouragement on the part of the people in the field of science and engineering who are working in and for the Government, and I think that anyone examining into this problem at the present time cannot avoid looking at this problem."[10]

Other experts in the field of education, industry and government laboratories have stated that there is no question but what a certain number of senior scientists and possibly young scientists of outstanding backgrounds have refused to work in the field requiring high security clearance because of possible publication and embarrassment due to misquoted information, and so forth.

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10. <u>Ibid.</u>, p. 444.

It has been reported that other highly qualified engineers and scientists have been cleared as far as security is concerned but are still reluctant to work under security conditions. Dr. Donald Quarles, acting as the Assistant Secretary of Defense for Research and Development, stated in an address at Fort Monmouth Laboratory in 1954:

> "We all recognize that there is a problem in this area. Scientists and engineers working on military related research and development have to be screened from the security standpoint. This is elementary from what we know about the Soviet techniques of infiltration and subversion. It is particularly applicable to our scientists since they possess knowledge of our most advanced technology and plans. Great loyalty and devotion have been the rule here. Disloyalty has been the rare exception, but unfair publicity about the exceptions has damaged all. ... This represents an area which we must study carefully to insure optimum results. There is an obligation on all for use in the administration of government research and development to use wisdom and understanding of the values involved, the positive values of the contributions that scientists make as well as the negative values of security against improper disclosures."[11]

Dr. James Killian has expressed the view "that maintaining our leadership (in military weapons) is far more important than sitting on our secrets, and that sitting on our secrets will not be the way to maintain

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11. Department of Defense Press Release No. 920-54 dated September 30, 1954.

that leadership, but the way to do it is to create advances faster than our enemy."[12]

There has been considerable expression by outstanding scientists and technical leaders that scientific and technical data is being withheld from other sections of our universities, private industry and Government Laboratories due to security. There undoubtedly are numerous examples of mis-application of the security seal to types of data and scientific information that should be widely distributed throughout the scientific family or community. However, from the limited knowledge of this author, any contractor or interested individual that has been given a satisfactory security check and has a need-to-know data can obtain it through the technical agencies, his unidersity, or his section of private industry. Undoubtedly exchange of information at all levels is hampered by the security procedures. However, I submit that the Government publications of known data and scientific results receive wide distribution throughout our scientific community. Relatively little data obtained under the basic research program is restricted due to the security classification. I further submit that the exchange of scientific data and information in the scientific community as a result of Government Research and Development is faster, more re-

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12. Riehlman Hearings, Op. cit., p. 442.

vealing and more freely exchanged than if this type of research data were obtained in a Research and Development Laboratory financed primarily by private industry and/or a university for the following reasons. If the research and development was conducted in a Research Laboratory of private industry, there would be certain considerations of proprietary rights and the feeling of 'let's keep this information here for the advantage of our corporation.' In the case of a university, the information would only be made available to those directly associated with the research project leader. It is my opinion, however, that in normal university cycles, the funds available to produce reports and give them wide distribution tend also to limit the distribution of scientific data. Within reason and with a few exceptions, the opinion of this writer is that the security restrictions preventing the circulation of data obtained under Government contract is not as restrictive as the financial or proprietary restrictions on data obtained in universities or private industry.

CIVIL SERVICE RESTRICTIONS AND REGULATIONS

The classification system within the Department of Defense is administered in various types, shapes, forms, and ways. For example, in the Department of Defense (The Secretary's Office), an operating official

calls in a classification expert and states in general what pay level he wants to pay an individual and describes the job that is to be done. It is my understanding that the classification expert then returns to his office and writes up a job description encompassing the duties of the individual, stating the approximate pay scale, and stating necessary qualifications to comply with civil service regulations.

In the case of the Navy Department, the classification system requires that the supervisor or the incumbent prepare his own position description without assistance from classification personnel, and without reference to what the pay will be for that job when it is evaluated. From personal experience in a large reorganization recently, I can state that this is extremely time-consuming to the supervisor, to the individual, to the administrative and to clerical help alike. As stated in the Riehlman Committee Hearings, one individual estimated that it frequently took as much as 80 hours of a supervisor's time to obtain approval of a position description for a subordinate.[13] In my opinion, 80 hours is over and above that required for the normal processing of a position description, but from processing a large reorganization a year ago, the incumbent knows of several hundred position descrip-

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13. Ibid., p. 705.

tions being re-evaluated that required over 60 hours of effort from various levels within the organization before the position descriptions were in satisfactory form for approval. One year later many of the position descriptions are still being re-written and re-evaluated.

It is true that the classification system is a check and balance against unfair practices within civil service. The problem remains -- how can we make it more efficient, more productive, less demoralizing, and a better tool for the operating officials to use in selecting qualified, capable, engineers, scientists, administrators and managers? It is essential to select these individuals at the time they are looking for a job. If several weeks or several months elapse before it is determined if they are qualified for the job which you have, chances are they have located a job elsewhere.

FLEXIBILITY (RESEARCH AND DEVELOPMENT "IN-HOUSE VERSUS CONTRACTED")

The contractor-operated research laboratory eliminates to a certain extent some of the problems which arise as a consequence of military-managed research activities, such as civil service regulations, lack of clear line of authority between supporting military activities and the civilian scientific community, and possibly the most important, a certain degree of

flexibility on expenditure of funds within a weapons systems area once they have been approved by all the reviewing authorities including the Department of Defense, Bureau of the Budget, the President, the Senate, Congress, etc. It has been stated that under these civilian-operated contract research laboratories a civilian scientist is permitted to operate more or less free of the routine military and civil service regulations and restrictions. The previously discussed security precautions required on government defense work remain in existence in identical form as to what they are in the military-managed research laboratory. The contractor-operated laboratory has the limitation that the government cannot guarantee a level of financial support in a fiscal year one, two or three years away. Therefore, on the part of the civilian-contracted manager there sometimes is considerable reservation in entering into such a contract. For the future considerations of a given agency within the Department of Defense the question must be asked, "What happens to my contractor-operated research laboratory if a home office management decides that it needs the essential scientists, engineers and administrators currently working on government projects?" In addition, there exists a certain type of research and development function that must be carried on in a continuing manner in the military laboratory. For example, the need for testing and

accepting functions which would cut across numerous companies, numerous types of equipment and require a large specialized costly facility for this type of work. In order to operate this large test and acceptance facility the engineers and scientists employed by the government at this installation must keep abreast of the latest developments in science and technology. Many employees at such activities maintain that this can only result if the test and evaluation people have a knowledge of the improvements, recent discoveries and recent advances in the technology pertaining to the work which they are performing.

There are numerous cases where private industry either is unwilling to undertake a project which the government desires to put on contract or the facilities are unavailable in private industry or in the universities. Frequently, the objectives of an educational institution might in general be in conflict with the terms of the government contract. That is to say, the educational institution during normal peace time might have as its primary objective the training and education of engineers and scientists in terms of broad technology and broad science. The staff's management, professional teaching scientists, etc., of the university should be occupied full time in this area, especially in areas where shortages exist, instead of working on government research and development contracts. In conclusion, it

should be stated that for the security of the country in the long run, it is possibly best that alternative arrangements within the military-operated research laboratory and the civilian contractor-operated research laboratory at a university or at an industrial plant should contain certain flexibilities. In order to insure that the government has a nucleus of experts in science, technology, administration and management, it must maintain certain research laboratories which employ highly qualified civilians and military in all the above-mentioned categories. All known means available must be exerted to make the military research and development laboratories attractive and desirable for both military and civilian employees and the emphasis on team play, cooperation and coordination, with each individual having his specific duty to perform, insures the government an "in-house" research program both as far as keeping abreast of the sciences and to insure its continual control and adequate knowledge as far as testing, acceptance and future areas in which research and development and explorations must be made.

None of the industrial companies, universities or government laboratories which were contacted during this thesis survey were willing to predict that any civilian company, or group of companies or universities, could expand and take on the responsibility for the administration, control and management of the Department

of Defense research and development program. It was a unanimous decision by all concerned that the magnitude, scope, difficulty, variety and extent of the Department of Defense research and development program were so broad that the existence of various review boards, committees and coordinating agencies within each of the services -- Army, Navy and Air Force -- was required. A government review agency for coordination, such as the Assistant Secretary of Defense for Research and Engineering, is required to consolidate, coordinate and review this enormous program before presenting it to the Bureau of the Budget, the President and the Congress.

Recently the Graduate School of Business Administration at Harvard University conducted a survey of a large segment of American industry for research spending which illustrates the following. It was found that among the American industries surveyed, the primary aim of research is to improve present products and processes which accounts for 50 per cent of the research funds -- known as applied research. The secondary aim by American industry -- creating new products and processes -- accounts for 42 per cent of research funds. This is also included in the type of research known as applied research. The third category, basic research -- research uncommitted to specific problems -- represented only eight per cent of research

spending.[14] Therefore, 92 per cent of the research spending in the American Industry is devoted to applied research, four per cent to basic research and four per cent to other.

After reviewing the above considerations of expenditures by private industry, it is reasonable to expect that one company would not want to make its findings and research data available to a competitive company that did not conduct a research and development program of its own either in applied research or in basic research. The overwhelming pressures and emphasis on applied research in private industry is best illustrated by the following:

> Management, brought up through the ranks of sales and production, does not act and think on the same scale as research. The immediacy of management's need for a new gimmick to meet the competition of the moment is inconceivable to a man who has seen a vision of space travel, computer-operated factories, health based on perfect balance of life process.[15]

From the above quotation it can be seen that the same types of differences of opinion which are referred to as civilian in a government-owned military-managed laboratory appear in private industry owned and

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14. Dearborn, Op. cit., p. 68.
15. "The New World of Research", Business Week, (May 28, 1955), pp. 104-132.

managed by a single company, and in this case it comes out under the heading of management versus research. In fact at this point I can draw the conclusion that there is more similarity between the military-(military-civilian) manager and the private industry manager than there is between the scientist and the military manager or the private industry manager. The scientists in the military program and in private industry feel that they are interested primarily in basic research which can generally be termed as fundamental research, such as the discovery of new push-button warfare weapons in the military and new modern glamour items in private industry.

The military profession and the industry manager, in contrast to the above, are generally oriented toward immediate improvement on either military weapons or on existing items now in production or on sale in industry, in other words, immediate use of applied research for the immediate improvement of existing products. The immediate cause of dissatisfaction or the general feeling of discontent may not be recognized by either the scientist in industry or the scientist in the military research and development laboratory. Therefore, in private industry he tends to blame management, sales, production and others not familiar with his product, whereas in the military he simply blames the military administration and control. A secondary source of general uneasiness and dissatisfaction which is not

recognized by the scientist in either military-managed, private industry laboratories or universities is the underlying fact that research and development support is expensive. Large sums of money which are required for temporary equipment, new designs, new features and new experiments, must come from other operational expenditures of the military, universities or private industries. Therefore, it becomes an active competition between one phase of the organization and another.

In all levels of economy one of the primary problems facing the university, the private industry and the military is to obtain adequate support for basic research, long-range planning and for research and development. The research and development program, basic, applied and long-range, is in competition with the production, sales, logistics and supply phases of all our businesses. In the universities the amount of money allocated to basic research and applied research is in competition with other sectors of the budget for the operation and maintenance of the university. In summary, it can be stated that research and development within the Department of Defense, within private industry, and within our universities has in the past 15 years made significant advances and has obtained considerable recognition. In the future, our military planners,our industrial managers and our university staffs must realize there will be production efficiency increases,

new products, new weapons systems, or new push-button warfare items, etc., available to them for the mere support of a small percentage of their total budget to basic and applied research and development. Also, universities and educational institutions must be encouraged to devote a substantial portion of their budgets into the search for fundamental knowledge, basic research, etc., and to make this information available to the engineers, scientists and students as soon as practicable.

DECENTRALIZATION

An important consideration in the military research and development program is, "How much should we decentralize?" Mr. Alfred P. Sloan, Jr., discussing the advantages of the decentralized management of General Motors' several enterprises, expressed the following:

> "We realize that in an institution as large as General Motors, any plan that involves too great a concentration of problems upon a limited number of executives would limit initiative, would involve delay, would increase expense and would reduce efficiency and development. Further it would mean an autocracy, which is just as dangerous in a great industrial organization as it is in the government. Aside from the question as to whether any limited number of executives could deal with

so many diversified problems, in so many places, promptly and efficiently."[16]

It is the opinion of this author that the above quote applies equally well to the military research and development program; the military research and development program should be decentralized as much as possible.

COMMUNICATION AND DISSEMINATION OF RESEARCH AND DEVELOPMENT INFORMATION

The government in my opinion does an excellent job of making reports, such as come from all agencies and parts of the government, available to all interested sections of the Government, private industry and universities by publishing major reports in the U. S. Government Printing Office and selling them for a nominal fee. In addition, each government bureau produces reports on its projects of a classified nature and these are available to all persons with a need to know and who have the proper security clearance. In addition, there are many and numerous unclassified publications. The magazine Data reports bi-weekly in summary fashion

16. Alfred P. Sloan, Jr., "Monopoly and Free Enterprise", by George W. Stocking and Marion W. Watkins, Twentieth Century Fund (1951), New York, New York, p. 63.

significant items which have been published by over 31 publishing concerns and 17 technical information officers. This data is presented in such a fashion that if you want more than the summary you write to the magazine and it will send the complete article.[17] Publications which the digest include as part of their agency survey letters are "Naval Aviation News", "Bureau of Ships Journal", "Air Force Information Services Letter","Air Force Air Research and Development Command News", "Office of Naval Research Reviews", "Naval Ordnance Laboratory Reports", "General Staff College Military Review", "Army Information Digest", "Army Aviation Digest", "Bureau of Supplies and Accounts News Letter", "Department of Defense Press Releases", "Commerce Department Releases", "Bureau of Standards Releases", and the "AEC Atomic Energy Reports", to name just a few. There are many more unclassified reports available -- in fact there are too many to ennumerate in a short paper of this sort.

Keeping tab on the nation's defense problems takes a lot of talking. Pentagon personnel make 135,000 calls daily, using 20,000 phones connected by 90,000 miles of cable.[18]

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17. Data, "Government Research and Development Digest", Box 6026, Arlington 6, Virginia.
18. Washington Post, Associated Press, (February 26, 1957).

Mr. A. D. Kaplan of the Brooking Institute, Washington, D. C., in his article "The Big Enterprise in a Competitive System", stated:

> "The increase in government employment may also be regarded, in part, as a response to the new requirements for making the opportunities of our rapidly advancing technology widely available."[19]

INDUSTRY EXECUTIVES' VIEWPOINT ON GOVERNMENT RESEARCH RELATIONSHIP

Mr. Allen Abrams, Vice President, Marathon Corporation, reported:

> "It appears that nearly all large companies in at least a few fields have carried on some research for the Federal Government. Some of these undertake such research only if the assignment fits their own background and present situation, if they have the manpower, and if they hope to produce results beneficial both to the government and to themselves. Other companies will take contracts only if no one else can do the work, and hence it becomes a patriotic duty for them to accept.
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> ....
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> "There is a marked criticism (a) of the overwhelming magnitude and variety of research contracts, (b) that invitations to bid are too widespread and thus many companies spend heavily

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19. A. D. Kaplan, "The Big Enterprise in a Competitive System", The Brooking Institute, Washington, D. C., p. 73.

on estimating without getting any awards, (c) that certain government agencies use a procurement type of approach in trying to specify research as though it were hardware."[20]

Favorable and important improvements between government and industry have been made in the last few years, possibly due to the increasing experience of government officials or to the better attitude of government toward industry. Several companies have stated that cooperation, coordination and friendship are good at the top level and that complications arise only at the lower levels, due principally to lack of contact.

Government-industry research relations on a large scale are relatively new. This type of operation has brought together people who think and work under specified rules and regulations with other people whose minds must, of necessity, be free to move into new and unexplored fields. While industrial executives strive to have unnecessary government restrictions removed, they should meanwhile exercise patience. Government research administrators should in turn have a scientific and engineering background so that they may have a better appreciation of research. Increasingly, govern-

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20. "Proceedings of the Ninth Annual Conference on the Administration of Research" (September 7-9, 1955), University Series, New York University Press; 1956. Hereafter referred to as: Ninth Annual Conference, p. 49.

ment administrators of the research programs do have scientific backgrounds and they maintain frequent contacts with other government agencies and with industry. This liaison will promote better operations of the program and should reduce duplication of effort. Security regulations should strive for a happy balance that will permit freedom of discussion, but will withhold vital information from hostile hands. Private industry believes that "red tape" will be reduced by selecting more competent research administrators, paying them better, and giving them wider discretion in making decisions. In general, executives state that if, in the years ahead, we can improve government-industry research relations as we have in recent years we shall have reason to be well satisfied.

REVIEW OF INDUSTRIAL RESEARCH, COORDINATION, CONTROL AND FINANCING

In the introduction of the book "Coordination, Control, and Financing of Industrial Research",[21] Mr. Robert T. Livingston stated that he would like to review the past five years of accomplishments by this

21. Fifth Annual Conference on Industrial Research; "Coordination, Control and Financing of Industrial Research", Albert H. Rubenstein, Editor, King's Crown Press, 1955, 429 pp.

group. He stated that it is important in research, as in any other activities, to look at the total operations from as many different viewpoints as possible, and particularly from the viewpoint of temporal development.

> "In 1950 the first conference on industrial research was held. This conference concerned itself primarily with cost of doing research and development. It was concluded at this conference that industrial research must pay off in the end. Every industrial researcher is faced with three problems in addition to his research problem itself: (1) Estimating the financial advantages which will accrue to his organization through this successful culmination of his project; (2) Estimating the time which will be required for the solution of the problem; (3) Estimating the probability of the successful culmination of his project."[22]

The second conference on industrial research was held in 1951, and this conference concerned itself primarily with "Personnel". It was concluded in this meeting that the researcher or scientist is not a run of the mill individual. To the military mind, to the industrial policy-maker and to top management of universities, private industry and government he may appear temperamental or phlegmatic but essentially he is a creator. In general this individual does not want to be concerned with administrative details. He feels that he must be provided with the environment in which the

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22. <u>Ibid.</u>, p. xvii.

creative power of the researcher can be released.

The third conference on industrial research was held in 1952 and the subject of this conference was "Design of Research Operations". This conference was a general review of where we are in research, where we are going and how we might do it better.

The fourth conference was held in 1953 and the subject was "Coordination and Control". During this conference a look at the research activities as an integral part of the larger company organization or corporate structure was examined. Two kinds of relationship resulted: (1) Interaction and integration within the research organization itself; and (2) The interaction and integration of the research organization with the rest of the company and the outside world.

In 1954 the fifth conference was held and the subject was "Economics". In general the subject of costs, budgeting, economics and financing were reviewed. The results of changes in management thinking and administration of research during the intervening four years since the first conference were examined.

Dr. David P. Hertz stated during the fourth annual conference on Industrial Research,

> "the communication of information in research has become both extremely difficult and, at the same time, very effective. Research in

industry has not just become another organ of the operating aspects of our companies, but is an integral part of our culture today."[23]

Numerous reports state that industrial research is booming and the Federal Budget for research alone is continuing its upward climb past the $2 billion mark.

RESEARCH AND DEVELOPMENT CONTRACTS AWARDED 1954-1956 INCLUSIVE

There has been published a list of the 300 companies and institutions receiving the largest amount of Military research and development contracts in the Fiscal Year 1954 through 1956 as prepared by the House of Representatives Select Committee on Small Business from reports supplied by the Department of Defense.[24] The first 15 companies in private industry with the largest contracts are:

Name of Company	Dollars
North American Aviation	$420,712,000
General Electric Company	338,102,000
Western Electric Company	264,195,000
Boeing Airplane Company	211,567,000
Hughes Aircraft	203,009,000
General Dynamics	146,978,000
Martin, Glenn L. Company	136,225,000

23. *Ibid.*, p. 3.
24. *Aviation Week*, (February 18, 1957), p. 90.

Name of Company	Dollars
Bell Aircraft Company	$133,723,000
Aerojet General	115,074,000
Westinghouse Electric	105,483,000
Northrop Aircraft, Inc.	105,174,000
Curtiss Wright Corp.	98,426,000
Radio Corporation of America	87,639,000
Lockheed Aircraft Corp.	84,253,000
Sperry-Rand Corp.	83,230,000

The total for the 239 firms in descending order represent $1,066,742,000 and there are no educational institutions or foundational research groups included in the first 239 firms.

The following tabulation will be the 240th firm in size through the 250th firm:

Mass. Institute of Technology	$61,169,000
Calif. Institute of Technology	50,673,000
Johns Hopkins University	38,695,000
Cornell Aeronautical Laboratory	24,814,000
Rand Corporation	21,462,000
University of Michigan	16,023,000
Columbia University	11,576,000
Stanford University	10,201,000
University of California	9,865,000
Batelle Memorial Institute	9,794,000

Universities and foundations total $412,828,000.

TRAINING PROGRAM FOR SCIENTISTS AND ENGINEERS

The National Science Foundation grants approximately 700 scholarships each year and many others supported by industry and private organizations.

It can be seen that the universities, private industry and the government are interdependent upon each other to an extent considerably greater than most people will admit. The immediate urgency of defense preparedness combined with the military duty of defending our country, as well as the duties and responsibilities of research, administrative and management personnel in private industry and universities to perform duties for their organization in the most efficient manner, must be coordinated toward the end result of the most research and development possible with the least expenditure of manpower and funds in the shortest time schedule possible. This extremely important and very urgent problem must receive consideration from all levels of management, policy-making, and decision-making organizations as well as the numerous review organizations within the Department of Defense, in the Executive Branch of the Government and in the Legislative Branch of the Congress.

COMPARISON OF UNITED STATES AND SOVIET SCIENTIFIC AND TECHNOLOGICAL PROGRESS

The question might well be asked why is such a large extent of our research and development work being applied to military weapons systems and research projects related to the defense of the United States?

In the opinion of this writer, the answer to this question rests with the assumption that the United States and its friends are convinced that in order to discourage aggressive acts by other nations we must be as strong as, or stronger militarily, than these nations. Therefore, the research and development effort in the United States must be at least equivalent to, if not greater than, that in the Soviet Union of Russia. Dr. James R. Killian, President of the Massachusetts Institute of Technology, is the chairman of a committee composed of 50 distinguished scientists and industrial leaders to make a report to the White House on the subject of the comparison of the United States and Soviet scientific and technological progress. This committee report is known as the "Killian Report". It has been reported that this committee presented an alarming comparison of the United States and the Soviet scientific progress and urged a vastly increased effort in scientific research and development in the United States.

Numerous articles have appeared stating that the Soviet Union is producing more physicists, mathematicians, engineers and scientists than are being produced in the United States. One figure estimated that during the past 20 or 25 years the Soviet Union has produced approximately 150,000 more engineers than have been educated in the United States. It has been further estimated that the engineers and scientists available

in the two countries (U.S.A. and U.S.S.R.) are now roughly equal in number. With all the advancements being made in the engineering and scientific fields it was stated in the Washington Post and Times Herald:

> Educators now estimate that 500,000 high school students are being taught mathematics by teachers who are not qualified to teach it. Another 300,000 are being taught by unqualified instructors. Yet this year American colleges graduated 57 per cent fewer men and women with licenses to teach science and 51 per cent fewer with certificates to teach mathematics than they did five years ago. The Nation's high schools need 6,000 new science teachers this fall but only 4,000 were graduated from colleges in June and of these only 2,000 will go into teaching.[25]

Looking at the statistics presented in the above quotation it seems evident that everything must be done within reason to make full utilization of those engineers, scientists, mathematicians and physicists desiring to work in those fields. There is no room for dissatisfaction, misunderstanding or misapplication of any of these technological and scientific people. It has been reported that in the Soviet Union nearly all of the engineers are doing engineering work, whereas in the United States only approximately 70 per cent of those qualified are working in engineering. Higher wages, personal recognition, and so forth, have been

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25. Washington Post and Times Herald (August 7, 1955), p. 21.

luring people away from their professions into management, administration, and so forth. Significant Weapon Systems advancement has been made since World War II. The emphasis on quality, specifications, superior weapons and weapon systems resulted in significant advancement in new and glamorous military weapons. Unfortunately, the Soviet Union and other communist countries have also been making significant advancements in the same types of weapons systems and areas. If much concern can be generated over the above figures on educational qualifications of individuals, it could be or should be concluded that an intesive look must be taken into our relative superiority with the existing scientific and technical manpower in order to maintain our position relative to the rapidly expanding scientific and technological resources within the U.S.S.R. One hundred per cent use of all facilities within the Government, within contractor operations for the Government, within universities and within private industry must be maintained. There is no room for dissatisfaction, disagreements, and unnecessary misunderstandings.

The world situation today requires a nice balance between the short range plan (up to five years) and the long range plan (five years and longer). The United States military forces must maintain strength to be in a position to exert power and to maintain preventive warfare with any of its potential enemies.

PATTERNS OF ORGANIZATION FOR APPLIED RESEARCH AND DEVELOPMENT

The importance of organization structure in research has been outlined by Mr. Herbert A. Shepard as follows:

> "Organizational structure is only one determinant of productivity and creativity. For creativity, organizational structure may matter a great deal less than personal selection. At the same time, creativity is as much a function of the environment as of the individual. Novel ideas and spirited effort are called forth by novel and spirited surroundings. The creativity and productivity of research and development groups appear to decline rapidly with length of association.
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> ....
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> "A method of evaluating and rewarding research personnel that provides a justified sense of recognition, professional worth and autonomy through changes in organizational and specialist status must be developed. This is most difficult to achieve where the laboratory staff has come to believe that advancement in the managerial hierarchy constitutes the only real success. Lastly, the top management group, incorporating a high level of talent in the scientific specialties represented in the laboratory, must be strong enough to encourage empire building and to destroy empires."[26]

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26. Herbert A. Shepard, "Patterns of Organization for Applied Research and Development", Industrial Relations Section, Department of Economics and Social Science, (Series 2, No. 52), Massachusetts Institute of Technology, p. 58.

HOW GOOD ARE CORPORATIONS' SCIENTISTS?

A thought-provoking comment by Mr. William H. Whyte, Jr., in his new book "The Organization Man"[27] has some extremely interesting implications. Mr. Whyte states that on the surface the corporation would seem to be on the verge of becoming one of the most enlightened of patrons. Some $1.6 billion of America's total research budget is now concentrated in the great laboratories that corporations have been building and proportionally, as well as in absolute dollars, this is a greater investment in research than industry has ever made before. ... If corporations continue to mold scientists the way they are now doing, it is entirely possible that in the long run this huge apparatus may actually slow down the rate of basic discovery it feeds on. ... Let us ask a brutal question, "How good are the corporations' scientists?" In the past industry has had many billiant ones -- Langmuir, Steinmetz, Carothers, and many others. Mr. Whyte reported that his colleagues recently made a study which yielded some surprising figures. His colleagues went to the foundations, such as Office of Naval Research, and the Atomic Energy Commission, to ascertain who the top 225 young

27. William H. Whyte, Jr., "The Organization Man", Simon and Schuster, New York (1956), p. 207.

scientists might be. It was thought that the nominations would probably split between industry and universities about half and half. To his amazement, however, he found that only about four of the 225 names were of men in industry. Fearing that the sample was biased, the committee then asked top academic scientists to think of scientists in industry and name any of them they thought top rank. After this study and effort, only 35 were forthcoming. Outside of their own subordinates, corporate research directors were hard put to it to think of anybody else in their field and industry worth naming -- and so were the university people. Most industrial scientists had to conclude that they neither know anyone nor are they known by anybody else. Several large industrial laboratories stood out as exceptions to the above comment.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This final chapter is a summary and conclusions chapter. The study has contributed a great deal to the writer's understanding of the research and development programs in government, private industry and universities.

1. The United States Military research and development program may be characterized as a mechanism for implementing the American determination to achieve technical superiority over potential enemies in terms of military weapons and equipment. It is the cornerstone of the United States military policy, and its success is dependent upon effective utilization of the Nation's scientific resources and productive capacity in the application of science and technology to present and further military needs.

   The results of our research and development program may well determine the division of power between the Communist Nations and the Free World. The outcome of our research and development efforts, therefore, influence directly the United States foreign policy and the life of every American.

2. The Department of Defense organization for the control and administration of research and development has had a short but exciting history. The Federal Government sponsors over 55 per cent of all research and development conducted in the United States. The Department of Defense administers 85 per cent of all the Government's research and development funds. This organization of Research and Development in the Government is the largest integrated scientific and technical endeavor that any nation has ever attempted. Therefore, it has become urgent to seek the most efficient organization, administration, and management of this program.
3. Before World War II, research and development in the United States was sponsored 60 per cent by Private Industry, 35 per cent by the Federal Government and 5 per cent by universities. Today research is sponsored 55 per cent by Government, 40 per cent by Industry and 5 per cent by the universities.
4. There are four types of contractual arrangements which have served to bring scientists into the Government program and as a result, there has developed a three-way partnership among the government, private industry, and the universities. In addition to the basic advantage of the partnership, the government has been able to obtain the services of scientists who might not be willing to work under the

restrictions of government employment. These contract arrangements also permit the government to carry on large scale operations with private industry and universities, largely free of political considerations. The four types of contracts are:

(a) Research and development aimed at improving existing weapons (most common type);

(b) "Master Contract" with a research institute or university under which individual research projects are handled without repeating the negotiation for each successive project;

(c) Extremely broad problem area, for example "Lincoln Laboratories operated by M.I.T."; and

(d) Procure the services of a special private corporation formed especially for this purpose, for example "Rand Corporation".

5. It should be noted that there are many coordinating agencies, policy committees, liaison committees, which have been created for the purpose of control, administration, and coordination of research and development projects within the Department of Defense, and with other agencies working closely with the Department of Defense. However, there is not planned nor does there now exist an organization for the review, control, and coordination of the research

and development work performed by the Department of Defense with that of other Governmental agencies.

6. The large increase in government employment may be regarded, in part, as a response to the new requirements for making the opportunities of our rapidly advancing technology widely available. It is, in the opinion of this author, the responsibility of the Federal Government to see that advantages or disadvantages do not result to any segment of our private industry or universities as a result of contracting with the Federal Government for research and development.

7. In the opinion of this writer, the scientific and military professions now accept the basic fact that cooperation, coordination, and workable partnership in research and development is essential, not only within military research organizations, but also in private industry and universities. The cooperation between military men and civilian organizations requires careful selection of both the military personnel and the civilian personnel who are to be dealing directly with the military. I submit that this workable partnership exists today and with proper support from the various review levels on the research and development budget procedures, the now-existing research and development science-military partnership will function effi-

ciently, promptly, and creatively. Many examples can be cited today where the military and science professions have collaborated fully and produced maximum use of scientific resources. In the years to come, this type of collaboration will become increasingly more important as a larger percentage of the research dollar is spent on the development of new futuristic weapons instead of minor improvements to old conventional weapons.

8. A general statement made by high officials in several companies interviewed was that the amount of work they currently have in their organizations is more than their current staff and organizations can handle. Pirating between industrial laboratories and from government laboratories (both civilian and military personnel) has been going on for years. At the present time however, the salary structure of the industrial and university research laboratories is considerably in excess of that at government installations, and it is profitable for these concerns to pirate from the government trained and oriented administrators, managers, and scientists. It has been stated by numerous companies on numerous occasions that as a policy matter it is the desire of the industrial laboratories to concentrate their best skills, best scientists and engineers on the products for which the company is in existence.

In other words, since there is a shortage of management, administrative, and scientific personnel, these companies feel that they owe to their stockholders the assurance that their most efficient and most productive employees will be working for the corporation on its primary goal of making a profit for the stockholder while at the same time producing the most advanced or most efficient equipment at the least cost to the customer.

If one considers from the government side of the question the desirability of maintaining a degree of continuity among the engineers, scientists, managers, and administrators who are familiar with the technical and management problems associated with government work, it becomes evident that immediate action must be taken to maintain these qualified individuals at military-owned and operated laboratories or at government-owned contractor-operated laboratories. Otherwise, following the normal promotion cycle, company officials and scientists will rotate in and out of the urgent defense projects at a rather rapid rate. After a person has been trained and oriented on the government contract he would be reassigned to some other duty within the company.

There exists a certain type of research and development function that must be carried on in a

continuing manner in the military laboratory; for example, the need for testing and accepting functions which would cut across numerous companies, numerous types of equipment, and require large specialized costly facilities for this type of work. In order to operate such a large test and acceptance facility the engineers and scientists employed by the government must keep abreast with the latest developments in science and technology. Many employees at such activities maintain that this can only result if the test and evaluation people have a knowledge of the improvements, recent discoveries and recent advances in the technology pertaining to the work which they are performing.

There are numerous cases where Private Industry either is unwilling to undertake a project which the Government desires to put on contract or the facilities are unavailable in private industry or in the universities. Frequently, the objectives of an educational institution might in general be in conflict with the terms of the government contract. That is to say, the educational institution during normal peace time might have as its primary objective the training and education of engineers and scientists in terms of broad technology and broad science. The staffs of the university should be occupied full time in this area, especially in

areas where shortages exist instead of working on government research and development contracts. In conclusion, it should be stated that for the security of the country in the long run, it is possibly best that alternative arrangements within the military-operated research laboratory, the civilian contractor-operated research laboratory at a university or in private industry contain certain flexibilities. In order to insure that the government has a nucleus of experts in science, technology, administration and management, it must maintain certain research laboratories which employ highly qualified civilians and military in all the above-mentioned categories. All emphasis and known means available must be exerted to make the military research and development laboratories attractive and desirable for both military and civilian employees. Emphasis on team play, cooperation and coordination with each individual having his specific duty to perform insures the government an "in-house" research laboratory to keep abreast of the sciences, to insure its continued control, and to insure adequate knowledge as far as testing and acceptance of equipment and instrumentation in areas in which research, development and explorations must be made by the Government.

9. Limitations on the Government's pay scale are causing

the loss of the best people from the top of the Government research and development organizations, and the Government is at a disadvantage in hiring new employees. In April, 1957, Private Industry is offering over $460 per month for engineers and scientists who are graduating from college in June, 1957. The maximum the Federal Government can pay under the existing regulations is $385. This writer submits that this is a very serious situation and that immediate corrective action is required.

10. Since 1947 each of the three military departments have made extensive use of an organizational device first used by the Office of Scientific Research and Development during World War II -- the contractor-operated center, usually in facilities which the government owns.

While these centers vary widely in the nature of their management control and the scope of their mission they all have one thing in common -- a primary contractual relationship with one or more of the military departments. This new and steadily growing arrangement has been particularly well-suited to research in broad problem areas associated with weapon systems development. Each military department has also used such centers for the conduct of operations research.

11. The Department of Defense engages in various scientific activities. Funds spent for research and development in the fiscal year 1954 were:

Service	Total $ (Millions)	% of Total Funds
Army	$350	3.5%
Navy	$450	4.0%
Air Force	$600	3.0%

Personnel in Scientific activities:

	Civilian Scientists in Research and Development	Other Supporting	Total Research and Development and Supporting
Army	9,160	33,369	42,529
Navy	9,720	24,811	34,531
Air Force	3,780	16,003	19,783
Non-Profit Institutes	3,000		
Commercial Labs.	1,180		
Private Industry	see Chapter IV		

(See Appendix 2 for Research and Development Expenditures in the United States.)

The breakdown of total engineers and scientists in the United States is not available to this author. It has been reported that the total employment of military and civilian employees in the Department of Defense research and development is

over 124,000 (engineers and scientists). Private Industry reports that they employ 157,000 engineers and scientists and that nearly one-third (or 52,000) are employed in research and development. Additional details on engineers and scientists employed in the United States are available in Chapter IV of this thesis.

12. There is a general feeling throughout the public that the necessary funds for research and development are available to the Department of Defense in the amount desired, requested or needed. This is <u>NOT</u> true. There are not now and there have not been since World War II sufficient funds to conduct all the research projects and weapons systems research for which the Military had firm Operational Requirements. Detailed funding information is available in Chapter IV on Private Industry, Cooperative Organizations, Non-Profit Laboratories, Commercial Laboratories, the large Private Foundations, and the Department of Defense.

13. It is obvious that the spending by the Department of Defense and other parts of the Federal Government has had an extremely important part in the growth of industrial research. It has been estimated that well over 60 or 70 per cent of the companies doing research and development work have contracts with the United States Government. In many cases, com-

panies feel that it is their patriotic duty and they must perform this government work. In most cases companies use many of their top technical people to work on government contracts. There is a growing feeling among industrial representatives today that as a long-term policy they would desire to do less government research and development work except in cases where the product being researched is a direct application to the product line normally manufactured, sold and distributed by the company concerned.

Most companies feel that by accepting government work their company benefits from the general know-how that is being developed. The company benefits from the accumulation of technical personnel with broader experience in coordination, management, and administration. This does, however, present a problem for nearly all companies conducting research on large government contracts. Their top technical personnel are taken out of their normal slots in the company organization and moved over to the government contract or to manage the laboratory owned by the government but being administered and managed by the contractor. These jobs normally place the individual two grades above his old billet in the old company. He is promoted immediately to have pay commensurate with the duties

he is performing. The real problem arises when the parent company desires to bring this individual back to its normal organization. If he is moved back into the company without reducing his salary or if he is moved into a billet which is comparable to the complexity, the coordination, the administration, and the management which he has had in the government contracted position, he moves one, two or three steps above the employees who have remained with the parent company. This creates a very undesirable situation. In effect it creates a situation where the word gets around to all other employees that the best way to get ahead in our own company is to work for our own company at a government laboratory -- one gets ahead faster this way.

16. To have research and development installations prepare budget estimates in complete detail 18 months in advance serves to waste a great amount of effort and encourages the padding of estimates as a protective measure. Research and development is, by its very nature, a constantly changing and substantially unpredictable effort and consequently, not readily adaptable to detail budgeting so far in advance.

17. Many of our government-owned military research and development laboratories are the best equipped, most modern and advanced laboratories in the world today.

These excellent facilities attract scientists and engineers desiring to work in the scientific field with new frontiers, dealing in new areas where unknown phenomena and expanding technical knowledge is growing rapidly.

18. An excellent objective of a combined scientific and technical program, composed of both military and civilian personnel, is as follows:

   a. The research program must be interesting and challenging.
   b. The need for the solution must be real and apparent.
   c. The leadership must be superior.
   d. The working conditions must be positively attractive.
   e. Great freedom must be provided for the individual initiative and for the investigation of individual and original ideas.
   f. The organizational structure must be effective, but "red tape" must be reduced to a minimum.
   g. There must be positive opportunities and incentives for interchange of ideas -- between members of the same group, between different groups, and between different laboratories or organizations having similar interests.
   h. The military needs must be expressed in terms

of combat problems, not solely in terms of technical specifications.

i. The attitude of the military must be not that they are ordering a device from the factory, but that they are inviting these scientists to help solve a technical or strategic problem.

19. It is the opinion of this author that the term "Military versus Civilian" is magnified out of proportion to its importance. In private industry if there is a difference of opinion between the scientists and the management, this is considered a normal difference of opinion between the scientists and management. In the military laboratories, this is termed difference of opinion or conflict between the scientists and the military, which in reality it is not. It is simply the normal difference of opinion between management and scientists.

20. Military security within the Government and within organizations contracting with the Government may be at the present time one of the things that is most hazardous to our future research and development activities in this country in relation to military problems. It has been reported that highly qualified engineers and scientists have been cleared as far as security is concerned but are still reluctant to work under security conditions. This author submits that the security program is essential and

that we must do whatever we can to simplify the system, yet maintain an adequate degree of security.

21. The pragmatic, piece-meal approach of earlier days to our research and development is not adequate for our complicated, large-scale planning and administrative tasks which the last decade has set before us. Therefore, our government must do everything in its power to improve the management and administrative structure of the large military research programs as well as the program of the Atomic Energy Commission, the National Science Foundation and the National Committee of Aeronautics (NACA).

22. The Constitution places the responsibility for the support of research and development in the Federal Government. It states:

> We, the people of the United States, in order to form a more perfect union, establish justice, insure domestic tranquility, provide for the common defense, <u>promote the general welfare and secure the blessings of liberty to ourselves and our posterity</u>, do ordain and establish this constitution of the United States of America.

23. Universities feel that it would be dangerous to higher education if all funds for the support of basic research were to come from the Federal Government. Moreover, it would be doubly dangerous if

one agency, no matter how high-minded or well-managed, controlled all those funds. On the other hand, it would be dangerous to national security if the Federal Government did not continue to supply adequate funds for the support of basic research at universities. It can be stated today that survival depends upon continued scientific growth. The Federal Government is beginning to take its responsibility for the support of all kinds of research, applied and basic, but unfortunately industry is lagging far behind. The bill must be paid and if industry does not pick up the check, Government support of academic research will have to double in the next ten years.

24. The Government, Private Industry and Universities are interdependent upon each other to an extent considerably greater than most people realize. The immediate urgency of Defense preparedness combined with the military duty of defending our country, as well as the duties and responsibilities of private industry and universities, must be coordinated toward the end result of the most research and development possible with the least expenditure of manpower and funds in the shortest time schedule possible. This extremely important and very urgent problem must receive consideration from all levels of management, policy-making, and decision-making

organizations as well as the numerous review organizations within the Department of Defense, in the Executive Branch and in the Legislative Branch of the Congress.

25. While industrial executives strive to have unnecessary government restrictions removed, they should meanwhile exercise patience. Increasingly, government administrators of the research programs should have scientific backgrounds and they should maintain frequent contacts with other government agencies and with industry. This liaison will promote better operations of the program and should reduce duplication of effort. Security regulations should strive for a happy balance that will permit freedom of discussion, but will withhold vital information from hostile hands. Private industry believes that red tape will be reduced by selecting more competent research administrators, paying them better, and giving them wider discretion in making decisions. In general, executives state that if, in the years ahead, we can improve government-industry research relations as we have in recent years we shall have reason to be well satisfied.

26. It is predicted by this writer that unless the world situation changes drastically, the over-all expenditure for research and development in the United States will increase at approximately seven

to ten per cent annually. This estimate is based upon the assumption that the gross national product will increase between three and seven per cent annually.

27. Communication of information in research has become both extremely difficult and, at the same time, very effective.

28. None of the industrial companies, universities or governmental officials who were contacted during this thesis survey were willing to predict that any civilian company, group of companies or group of universities could expand and take on the responsibility for the administration, control and management of the over-all Department of Defense research and development program. It was a unanimous decision that the magnitude, scope, difficulty, variety and extent of the Department of Defense research and development program were so broad that the existence of various review boards, committees and coordination agencies within each of the services was required. It was further agreed that an organization of the size of the Assistant Secretary of Defense for Research and Engineering is required to consolidate, coordinate and review the enormous military research and development program before it is presented to the Bureau of the Budget, the President and the Congress.

29. Evaluated on the above criteria, it is this author's final conclusion that at the present time it would <u>not</u> be possible to contract out to Private Industry or to Universities the over-all control and administration of Military Research and Development.

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March 18, 1957
NUMBER 5129.1

ASD(R&E)

Department of Defense Directive

SUBJECT Responsibilities of the Assistant Secretary of Defense (Research and Engineering)

References: (a) DOD Directives 5128.7, dtd 12 November 1953, and 5128.11, dtd October 4, 1956, "Responsibilities of the Assistant Secretary of Defense (Research and Development)."

(b) DOD Directives 5129.1, dtd 8 December 1953, and 5129.4, dtd October 4, 1956, "Responsibilities of the Assistant Secretary of Defense (Engineering)."

(c) DOD Instruction 5100.3, dtd 27 October 1954, "Clarification of the Relationships of the Assistant Secretary of Defense (Research and Development) and the Assistant Secretary of Defense (Engineering)."

I. AUTHORITY AND PURPOSE

Pursuant to the authority vested in the Secretary of Defense by the National Security Act of 1947, as amended, and by Reorganization Plan No. 6 of 1953, the positions of Assistant Secretary of Defense (Research and Development) and Assistant Secretary of Defense (Engineering) are hereby combined into the single position of an Assistant Secretary of Defense (Research and Engineering). The Assistant Secretary of Defense (Research and Engineering) shall have responsibilities as assigned by this directive.

II. RESPONSIBILITIES

The Assistant Secretary of Defense (Research and Engineering) shall have the following responsibilities:

A. Providing advice and assistance to the Secretary of Defense and his staff on Department of Defense policies,

plans, and programs in the fields of research, engineering and development, including advice with regard to trends in scientific research relating to national security and the measures necessary to assure continuing and increasing progress.

B. Developing the policies and procedures required to assure that the research programs and projects of the military departments and other DOD agencies are sound and integrated and give appropriate emphasis to the basic and applied research required for the introduction of new types of weapons and equipment; and to assure that the nation's best scientific and technical talents are applied to the planning and prosecution of military programs.

C. Developing the policies and procedures required to assure that development programs and projects for weapons and military equipment planned by the military departments and other DOD agencies for service use meet the objectives without impairment to military effectiveness of (1) attainment of minimum number of types and sizes of weapon and equipment systems with least cost, effort and time; (2) sound design, including such factors as producibility, reliability, mobility, transportability, simplicity of operation, ease of maintenance, simplicity in logistics support and conservation of critical materials.

D. Reviewing and recommending the approval or disapproval of research programs and projects and development programs and projects of the military departments and other DOD agencies, which support budget estimates and apportionment requests and making recommendations to the Secretary of Defense for allocations from the research and development Emergency Fund.

E. Recommending the assignment of specific research and development programs and projects to a military department whenever it appears that military effectiveness may be increased, unwarranted duplication eliminated, and efficiency and economy promoted.

F. Developing policies and procedures in the field of maintenance engineering for weapons and military equipment to the end that the requirements of

economical and efficient maintenance will receive adequate attention during the design and production engineering phases of development and that maintenance and modification programs and operations of the military departments will be adequately planned and implemented; including the policies and procedures for the initial provisioning of spares and repair parts, and the timely availability of technical information, supporting facilities, equipment, and trained personnel needed for the maintenance of weapons and military equipment.

G. Enhancing the contribution of research, engineering and development programs to strategy by means of continuous interchange of information in these fields at appropriate levels with the Joint Chiefs of Staff and the military departments; by furnishing research, engineering and development information necessary for the development of joint strategic objectives and estimates; and by advising the Joint Chiefs of Staff when it seems desirable to establish joint requirements.

H. Exercising administrative direction of the Weapons Systems Evaluation Group and assuring that this group is responsive to the JCS and the OSD for operations analysis service.

I. Developing policies and procedures for promoting the conservation and efficient utilization of materials in development and procurement programs of the military departments.

J. Recommending policy for the Department of Defense, and representing or arranging for representation of the Department of Defense, with other governmental, nongovernmental and international organizations on research, engineering or development matters of mutual interest or responsibility.

K. Collaborating with the other Assistant Secretaries of Defense, the Joint Chiefs of Staff and other agencies within the Office of the Secretary of Defense on matters in which there exists a mutual interest or responsibility.

III. DELEGATION

The Assistant Secretary of Defense (Research and Engineering) is hereby authorized to obtain such reports and information

from the military departments as he may determine necessary to carry out the above responsibilities; and is authorized and expected to insure effective implementation by the military departments of established Department of Defense policies, plans and programs within his field of responsibility.

In the performance of these functions, the Assistant Secretary of Defense (Research and Engineering) will, to the extent practicable, utilize the advice, assistance and appropriate facilities of the military departments. Such utilization shall not, however, be so construed or so utilized as to circumvent the established command channels through the secretaries of the military departments for the formal communication of approved policies, plans or other directives.

IV. CANCELLATION

References (a), (b) and (c) are superseded and canceled. This Directive likewise supersedes all other unreferenced directives, instructions, and memoranda to the extent that they are inconsistent herewith. Formal action to cancel or modify all such unreferenced documents will be taken as soon as practicable.

V. EFFECTIVE DATE

This Directive is effective immediately.

Signature redacted

Secretary of Defense

NATIONAL SCIENCE FOUNDATION

REVIEWS OF DATA ON RESEARCH & DEVELOPMENT

WASHINGTON 25, D.C.

Number 1 NSF 56-28 December 1956

Expenditures for Research and Development in the United States, 1953

Introduction

A major aspect of American culture and technology in recent decades has been the growth of research and development in the natural sciences. As human and other resources devoted to research have increased in volume, a need has arisen for data on the total volume of this activity and the nature and magnitude of its components. In attempting to meet this need,[1] the National Science Foundation has undertaken a group of surveys [2] on expenditures for research and development conducted by organizations in the various sectors of the economy, using the year 1953 as a starting point.

Estimates now available from this first effort to obtain a systematic across-the-board picture (presented in chart 1) indicate that about 5.4 billion dollars were spent on the conduct of research and development in the natural sciences in the United States in 1953. This figure, which does not include expenditures for capital equipment, was roughly 1.5 percent of the gross national product of 363.2 billion dollars for the same period.

R & D by Major Sectors

The organizations which participate in research and development in the natural sciences come from all parts of the economy. For analytical purposes they are often classified by the appropriate sector of the economy—government, industry, colleges and universities, or "other institutions."

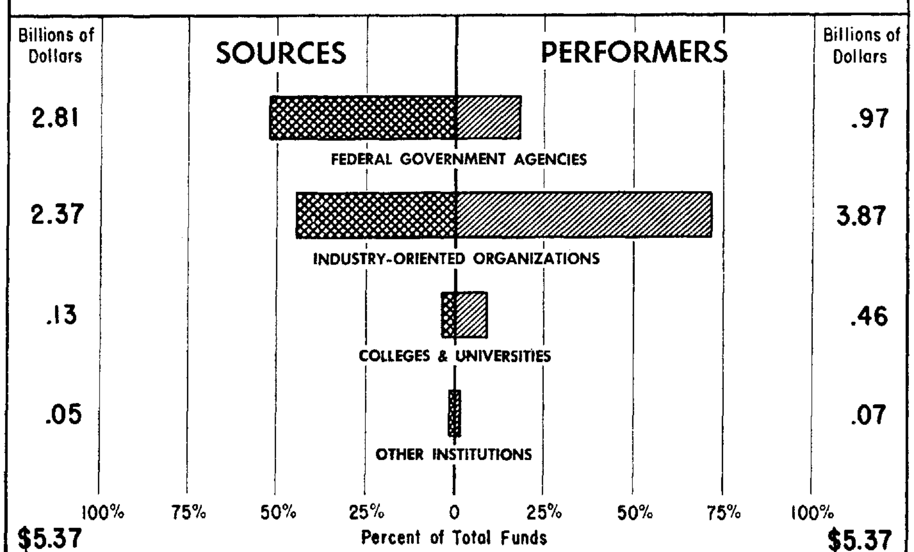
In the present analysis, the government or public sector consists only of agencies of the Federal

[1] Some notable earlier estimates of the volume of scientific research and development were presented in: National Resources Planning Board, *Research—A National Resource*, Vols. I and II, 1938 and 1940; Office of Scientific Research and Development, *Science, the Endless Frontier*, 1945; The President's Scientific Research Board, *Science and Public Policy*, Vol. I, 1947; and Department of Defense, *The Growth of Scientific Research and Development*, 1953.

[2] A list of available NSF reports based on these surveys appears on p. 4.

Chart 1

THE FOUR SECTORS AS SOURCES OF R & D FUNDS AND AS R & D PERFORMERS, 1953



Note: Dollar Detail May Not Add to Totals Because of Rounding

SOURCE: National Science Foundation

TABLE 1.—THE FOUR SECTORS AS SOURCES OF R & D FUNDS AND AS R & D PERFORMERS [a], 1953 (PRELIMINARY)

Major sectors	As sources of R & D funds: Millions of dollars	As sources of R & D funds: Percent of total	As R & D performers: Millions of dollars	As R & D performers: Percent of total
Federal Government agencies	$2,810	52	$970	18
Industry-oriented organizations	2,370	44	[b] 3,870	72
Colleges and universities	130	3	[b] 460	9
Other institutions [c]	50	1	[b] 70	1
Total	5,370	100	5,370	100

NOTE.—Detail may not add to totals because of rounding. Percentages are calculated on the basis of unrounded figures.

[a] Notes on some of the terms and data appearing here are on p. 4.

[b] Includes funds from the Federal Government for the conduct of R & D at research centers administered by organizations in this sector under contract with Federal agencies.

[c] The "other institutions" sector includes privately endowed foundations, health agencies, academies of science, and professional societies. Some undistributed funds—less than 10 million dollars—are also included.

Source: National Science Foundation.

Government. No data are available on a national basis on research and development by state and local governments but the volume of funds involved at these levels is not large.[3]

The NSF surveys included data on research and development by the important and relatively new type of unit for the conduct of research—the "research center." This is a laboratory or similar research establishment supported wholly or predominantly by the Federal Government but operated under contract by industrial, university, or independent organizations. Although created by Federal agencies, such research centers are closely identified in their work with the sector by which they are managed. Hence, data relating to them are included with these sectors in the analysis in tables 1 and 2.

[3] The R & D activities of selected states—Connecticut, New York, North Carolina, Wisconsin, California, and New Mexico—have been surveyed for the NSF.

Five groups of organizations comprise the industry-oriented sector: private industrial firms, which accounted for over 90 percent of the research and development performed in the sector; cooperative research organizations such as trade associations and technical societies; non-profit research institutes; commercial laboratories; and federally supported research centers or laboratories operated by industrial concerns.

The colleges and universities sector consists of institutions of higher education with substantial

TABLE 2.—TRANSFERS OF FUNDS AMONG THE FOUR SECTORS AS SOURCES OF R & D FUNDS AND AS R & D PERFORMERS,[a] 1953 (PRELIMINARY)

[*Dollar data in millions*]

Major sector		R & D PERFORMERS: Federal Government agencies	Industry-oriented organizations	Colleges and universities	Other institutions	TOTAL	Percent of total R & D
SOURCES OF R & D FUNDS	Federal Government agencies	$970	[b] $1,520	[b] $280	[b] $50	$2,810	52
	Industry-oriented organizations	....	2,350	20	....	2,370	44
	Colleges and universities	....	....	130	....	130	3
	Other institutions	....	....	30	20	50	1
	TOTAL	$970	[b] $3,870	[b] $460	[b] $70	$5,370	100
Percent of total R & D		18	72	9	1	100	

NOTE.—Detail may not add to totals because of rounding. Percentages calculated on the basis of unrounded figures.

[a] Notes on some of the terms and data in this table appear on p. 4.

[b] Includes funds from the Federal Government for the conduct of R & D at research centers administered by organizations in this sector under contract with Federal agencies.

Source: National Science Foundation.

research programs and of the Federal research centers operated under contract by educational institutions. Included in institutions of higher education are graduate and professional schools and affiliated research organizations.

The "other institutions" sector includes private philanthropic foundations, health agencies, academies of science, and professional societies as well as several federally supported research centers operated by independent organizations.

Analysis of R & D Funds

The many types of resources which flow into research and development are, of course, part of the larger stream of resources which sustains the Nation's entire productive activity. The NSF surveys attempted to identify separately the cost of the resources used in the conduct of research and development by the various sectors of the community during the year in question, 1953.

The nature of R & D activity varies greatly among the many participating organizations. Some perform little or no research and development themselves, but act instead as sources of funds for work done by others. Some perform research as a major activity, partly or entirely with financing from outside sources. Others act as both a source and a performer. The role of each of the sectors as a source and performer is summed up in a two-column ledger in table 1 and chart 1. The transfers of funds from sources to performers are presented in table 2.

Major Sectors as Sources of R & D Funds and as Performers of R & D

In the R & D ledger in chart 1 and table 1 the source-of-funds or financing-of-research side shows the volume and percent of total reported funds which came from the organizations in each of the sectors; the performance-of-research or use-of-funds side shows the cost of research and development performed by organizations in each sector.

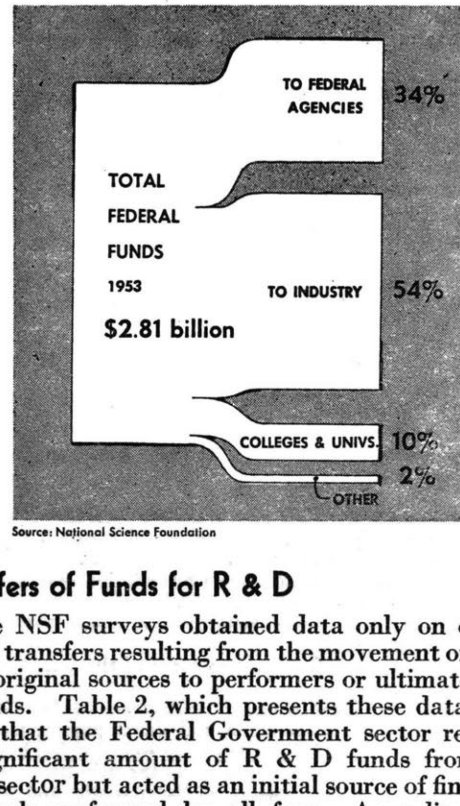
The sources data reveal that the Federal Government and industry-oriented sectors together provided more than 95 percent of the financing of research and development. The Federal Government alone furnished more than the other three sectors combined. Funds from the university and "other" sectors were less than 5 percent of the total.

In contrast to the sources picture, which points to near equivalence in the financing of the Nation's research and development by the Federal Government and industry, the performers' side of the ledger shows one sector predominating. Research and development performed by industry-oriented organizations amounted to almost three-fourths of the total. The dollar volume of research and development performed by Federal Government agencies in their own facilities was one-fourth that performed by the industry sector.

In other words, the Federal Government sector was primarily a source of funds, while the industry-oriented sector combined the two functions, with a larger volume as performer than as source. The characteristic role of the university as a performer of research emerges from the 3:1 ratio between the reported dollar volume of research performed and that financed by this sector. It should be noted that the estimate of 130 million dollars for colleges and universities as a source of research and development funds does not include hidden costs such as the salaries of most principal investigators and other contributions made by the educational institutions for work for which funds are provided by the Federal Government.

Chart 2

FLOW OF FEDERAL FUNDS INTO RESEARCH & DEVELOPMENT, 1953



Source: National Science Foundation

Transfers of Funds for R & D

The NSF surveys obtained data only on certain major transfers resulting from the movement of funds from original sources to performers or ultimate users of funds. Table 2, which presents these data, indicates that the Federal Government sector received no significant amount of R & D funds from any other sector but acted as an initial source of financing for work performed by all four. According to a more detailed analysis, in chart 2, of the recipients of the 2,810 million dollars in Federal funds, the Federal Government did about a third of its research and development itself in its own laboratories and relied on contracts with industry-oriented groups for the performance of a little more than half the total. These were for the most part research and development contracts. Only a part of the research and development conducted by industry with funds from Federal production and procurement contracts was reported in the NSF surveys. About a tenth of the federally-financed research and development was carried on in colleges and universities.

In addition to performing over half the research and development financed by the Federal agencies, the industry-oriented sector performed a still larger

TABLE 3.—R & D PERFORMED BY THE COLLEGES AND UNIVERSITIES SECTOR, BY SOURCES OF FUNDS [a], 1953 (PRELIMINARY)

Source of funds	Volume of R & D performed by colleges and universities	
	Millions of dollars	Percent of total [b]
Federal Government agencies	[c] $280	61
Industry-oriented organizations	20	4
Colleges and universities	130	29
Other institutions	30	6
Total	460	100

[a] Notes on some of the terms and data appearing here are on p. 4.

[b] Percentages calculated on the basis of unrounded figures.

[c] Includes funds for the conduct of R & D at research centers administered by colleges and universities under contract with Federal agencies.

Source: National Science Foundation.

volume of research and development with 2,340 million dollars of its own. Industry-oriented sector funds reported as going for university research and development were under 1 percent of the total funds originating in industry.

The colleges and universities received funds from the three other sectors but did not provide funds to them. As Table 3 indicates, three-fifths of the financing for university research and development came from the Federal Government and somewhat more than a quarter from the sector itself.

Limitations of the R & D Funds Analysis

The foregoing sector analysis of funds for research and development is designed to provide information on a vital portion of our economy in terms of a common unit—dollars—which makes it possible to relate this information to quantitative knowledge on other aspects of the economy. But such a presentation tells only part of the research and development story.

Because of the varying concepts and accounting systems of the institutions involved, the dollar data are, in the first instance, only an approximation of the "costs" of research and development. Furthermore, as is well known, costs vary greatly from sector to sector and among institutions within a given sector. A striking but by no means the sole example of this is the well-known difference between industrial and university pay for the same type of work. Taken together with the wide prevalence of "unpaid research" done on the university researcher's own time, this difference in cost warns of the pitfalls underlying any assumption that a dollar necessarily represents the same amount of work from one sector to another.

Notes

The estimates of totals and transfers presented in tables 1 and 2 were derived from data obtained through a group of related surveys of expenditures for research and development carried on by the National Science Foundation during the past two years. Returns from some of the surveys are still being processed and the entire presentation must therefore be regarded as preliminary.

The notes which follow explain some of the terms and data herein employed.

Research and Development.—Because of the wide diversity of concepts of research and development, somewhat different definitions of this term were followed in the various NSF surveys. The central idea in all the definitions was that of research and development as "systematic and intensive study directed toward a fuller knowledge of the subject studied and use of that knowledge directed toward the production of useful materials, devices, systems, methods, or processes, exclusive of design and production engineering."

The data on research and development refer in general only to the natural sciences. As defined in the NSF surveys, the natural sciences consist of the physical sciences: astronomy, chemistry, earth sciences, engineering, mathematics, and physics; and the life sciences: biological, medical, and agricultural. However, data from several surveys included some funds for research in psychology and the social sciences.

Funds.—Dollar data here presented are based on estimates from a great variety of institutions with somewhat differing understandings of "costs" and "expenditures". In the case of Federal agencies, moreover, estimates were based on obligations rather than expenditures since information on transfers to the other sectors was available only for obligations. The word "funds" is used here in order to encompass these differences.

1953.—Because of the diversity of accounting procedures, already noted, the present estimates for 1953 are based on a number of different fiscal years beginning during calendar year 1953. The entire Federal agency survey and much of the university survey, for instance, were based on the Federal fiscal year July 1, 1953–June 30, 1954. In the industry-oriented sector the majority of private firms—representing the bulk of the funds involved—reported for fiscal years which either coincided with calendar 1953 or began shortly after the opening of calendar 1953.

NSF Reports on Research and Development.[4]—Reports published by the National Science Foundation on R & D expenditures in 1953–54 are:

Scientific Research Expenditures by the Larger Private Foundations. Prepared for NSF by F. Emerson Andrews, Russell Sage Foundation. 1956.

Research by Cooperative Organizations. A Survey of Scientific Research by Trade Associations, Professional and Technical Societies, and Other Cooperative Groups, 1953. Prepared for NSF by Battelle Memorial Institute. 1956.

Research and Development by Nonprofit Research Institutes and Commercial Laboratories, 1953. Prepared for NSF by the Maxwell Research Center, Syracuse University. 1956.

Science and Engineering in American Industry: Final Report on a 1953–54 Survey. Prepared for NSF by the U. S. Dept. of Labor, Bureau of Labor Statistics. 1956.

Federal Funds for Science IV. The Federal Research and Development Budget. Fiscal Years 1954, 1955, and 1956. 1955.

Federal Funds for Science V. The Federal Research and Development Budget. Fiscal Years 1955, 1956, and 1957. 1956.

[4] Copies of these reports may be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

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